(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
13 September 2001 (13.09.2001)

PCT

(10) International Publication Number
WO 01/67413 A1

(51) International Patent Classification[7]: G08B 13/14

(21) International Application Number: PCT/US01/07389

(22) International Filing Date: 8 March 2001 (08.03.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/521,257 8 March 2000 (08.03.2000) US

(71) Applicant: MOTOROLA INC. [US/US]; 1303 East Algonquin Road, Schaumburg, IL 60196 (US).

(72) Inventors: QUADERER, James, G.; 302 Beechnut Avenue, Sunnyvale, CA 94086 (US). VEGA, Victor; 2062 Pheasant Drive, Hercules, CA 94547 (US). HATTICK, John; 1745 Ringel Court, Morgan Hill, CA 95037 (US). DAVIDSON, James, Richard; 18266 Crest Avenue, Castro Valley, CA 94546 (US).

(74) Agents: HUGHES, Terri, S. et al.; Motorola Inc., Intellectual Property Dept., 1303 East Algonquin Road, Schaumburg, Il 60196 (US).

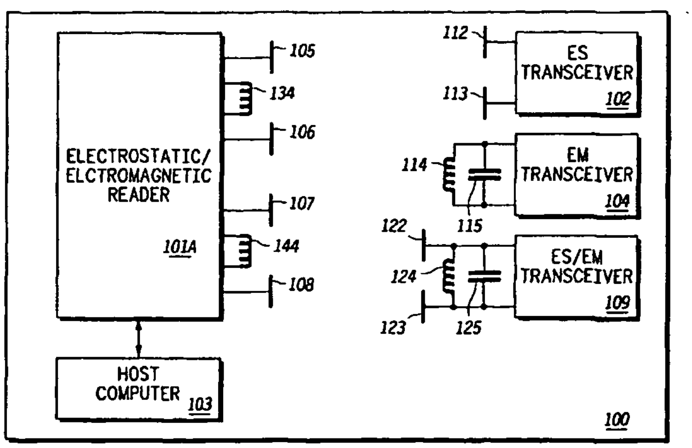
(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: ELECTROSTATIC AND ELECTROMAGNETIC COMMUNICATION SYSTEMS AND COMBINATIONS THEREOF



(57) Abstract: A radio frequency identification (RFID) system (100) employs electrostatic technology (101), capacitive (105, 106) coupling of electric fields, electromagnetic technology (101), inductive (134, 144) coupling of magnetic fields, and combinations thereof, to communicate power and data signals to and from a source device (readers) (100) and a remotely located transceiver (tags). In the combined electrostatic and electromagnetic communication system (100) of the present invention a single electromagnetic and electrostatic reader is provided that combines electromagnetic technology (101) with electrostatic technology (101) such that a reader (100) is backward compatible and can support either electromagnetic radio frequency identification (RFID) tags or electrostatic RFID tags. A reader (100) is designed to include both electrostatic electrodes (105, 106) and electromagnetic induction coils (134, 144) and incorporates additional modifications including those to a receiver in order for the reader (100) to support both electromagnetic RFID transceivers (104) and electrostatic RFID transceivers (102) in the combination electrostatic and electromagnetic communication system (100).

WO 01/67413 A1

ELECTROSTATIC AND ELECTROMAGNETIC COMMUNICATION SYSTEMS AND COMBINATIONS THEREOF

CROSS REFERENCE TO RELATED APPLICATIONS

This application is related to United States patent application Serial No. 09/061,146, filed 16 April 1998 by inventors Ted Geiszler et al, titled "REMOTELY POWERED ELECTRONIC TAG WITH PLURAL ELECTROSTATIC ANTENNAS AND ASSOCIATED EXCITER/READER AND RELATED METHOD; RADIO FREQUENCY IDENTIFICATION TAG SYSTEM USING TAGS ARRANGED FOR COUPLING TO GROUND; RADIO FREQUENCY IDENTIFICATION TAG ARRANGED FOR MAGNETICALLY STORING TAG STATE INFORMATION; AND RADIO FREQUENCY IDENTIFICATION TAG WITH A PROGRAMMABLE CIRCUIT STATE" and assigned to Motorola, Inc. the disclosure of which prior application is hereby incorporated by reference, verbatim and with the same effect as though it were fully and completely set forth herein.

Field of the Invention

This invention relates to communication systems, and more particularly to radio frequency identification (RFID) systems and RFID readers, writers, and programmers.

Background of the Invention

Radio Frequency Identification (RFID) technology allows information and/or data to be transferred remotely which provides a significant advantage in identifying persons, articles, parcels, and others. In general, to access identification data stored in a remotely located RFID transponder, transceiver, or tag, an RFID reader generates an energy field to activate the RFID transponder to retrieve data stored in the transponder . The data retrieved from the RFID transponder is then processed by a host computer system to identify the person or article that is associated with the transponder. While a transponder that derives its power from the energy field is known as a passive transponder, a transponder that has its own power source is referred to as an active transponder. RFID technology has found a wide range of applications including tracking, access control, theft prevention, security, etc.

RFID technology is more preferable than magnetic strip technology, which also finds applications in a few of the areas above. The reason is systems employing RFID technology do not require physical contact with a reader. Magnetic strip technology requires being swiped over the magnetic heads in a reader. As a result, the magnetic strip reader requires maintenance when the magnetic heads become dirty or magnetized. Additionally, magnetic strip technology is volatile in that it can be accidentally erased when expose to high magnetic fields. Consumers often experience this when the magnetic strip on the back of credit cards are no longer readable.

RFID technology should be distinguished from Radio ID technology which uses ordinary radio waves, or more precisely far field electromagnetic (EM) waves which are also known as radiation waves. Far field means the distance between the transceiver and transponder is great compared to the wavelength of the electromagnetic carrier signal used. An example of Radio ID technology is the Identify—Friend or Foe (IFF) systems used with military aircraft. Far field electromagnetic waves have a field strength that varies inversely with the distance involved.

In contrast, conventional RFID technology is based upon inductive coupling utilizing magnetic field waves. Conventional RFID technology operates in the near field where the operating distance is far less than one wavelength of the EM field. Unlike far field radio waves, the magnetic field strength is approximately proportional to the inverse cube of the distance from the source. In inductance-based RFID technology, a magnetic field is generated for use both as a power source for the transponder and for transferring data and clock information between the reader and transponder. Magnetic fields are generated by causing alternating current to flow in coils that typically have multiple turns. Inductance coils for communication of electromagnetic signals are usually a wire wound or etched metal coil. Using inductance coils adversely impacts the costs, manufacturability, and packaging flexibility of inductance-based RFID technology particularly when used with high number of RFID tags usually required in a system. Due to the prohibitive costs and high degree of manufacturing difficulty, electromagnetic RFID technology is not practical in high volume and low cost applications such as in disposable applications. The bulky packaging, which is typical for electromagnetic RFID, further limits its application to those where thickness in not of primary importance.

One of the more popular applications of electromagnetic RFID systems is for access control. An example is where an electromagnetic RFID transponder, commonly referred to as a badge, controls an employee's access to company buildings. Electromagnetic RFID readers are at the controlled entry point to the company buildings which either allows or denies access to a building when an employee brings a badge (EM RFID transponder) near an RFID reader. The electromagnetic RFID system often times has information about the employee to whom it was issued allowing more or less access to certain employees. Larger companies often times have many buildings with access control points that are spread out over the country or the world. Some employees are required to travel between these buildings and so often times the same system is employed at each building so that only one badge need be issued to an employee. Otherwise an employee is required to have multiple tags to enter buildings having the differing electromagnetic RFID systems.

In access controlled facilities such as buildings, visitors are often invited into the facility for business meetings or other reasons. Visitors to access controlled facilities often are issued paper visitor badges because they are often discarded at the end of a day. These paper visitor badges have no RFID technology and thus are unable to allow access to controlled buildings having an RFID reader. Furthermore it is difficult for an RFID system to trace the whereabouts or access of a visitor with a paper visitors badge. In using access control systems such as electromagnetic RFID, the electromagnetic tags or badges are usually only issued to employees requiring access and not visitors. This is due to the high cost of the electromagnetic RFID tags and the need for an inexpensive disposable badge for visitors.

Because there are many electromagnetic RFID systems in use today, as new RFID technologies, such as electric field/ capacitively-coupled systems, become available, they may have a difficult time in replacing the installed user base. Additionally, because the electromagnetic RFID systems are widely in use as access control systems, introducing a new technology all at once is difficult to do because of all the reprogramming and system support that is required. This is particularly the case when the electromagnetic RFID system has numerous electromagnetic RFID tags that would require replacement. Additionally the initial cost of replacing all electromagnetic RFID tags at once may be prohibitive. Furthermore, a company or other user with numerous electromagnetic readers

at different places, such as different buildings, may want to phase in any new technology over a period of time to see if it properly meets a user's needs. Alternatively they may want to avoid losing the investment which was made in electromagnetic RFID technology. Also, replacing an electromagnetic reader with a different RFID reader technology may cause the RFID tags to be incompatible. In which case two RFID tags may be required to enter different buildings having differing reader technology.

Thus, it is desirable to have an apparatus, system and method for providing electric field and/or magnetic field communication utilizing either capacitance-based technology and/or induction-based technology.

Brief Description of the Drawings

Various embodiments of the invention are now described, by way of example only, with reference to the accompanying drawings, in which:

FIG.1A is a system level diagram for a dipole exciter and receiver for the electrostatic/electromagnetic reader illustrating a typical electrostatic and electromagnetic radio frequency system where the present invention may be employed;

FIG. 1B is a system level diagram for a monopole exciter and receiver for the electrostatic/electromagnetic reader illustrating a typical electrostatic and electromagnetic radio frequency system where the present invention may be employed;

FIG. 1C is a system level diagram for a dipole exciter and a monopole receiver for the electrostatic/electromagnetic reader illustrating a typical electrostatic and electromagnetic radio frequency system where the present invention may be employed;

FIG. 1D is a system level diagram for the monopole combination receiver/transmitter for the electrostatic/electromagnetic reader illustrating a typical electrostatic and electromagnetic radio frequency system where the present invention may be employed;

FIG. 2 is a block diagram of electrostatic/electromagnetic reader of the present invention;

FIG. 3 is a block diagram illustrating the functional blocks for receiving ES or EM signals;

FIG. 4A is a block diagram illustrating details of a first receiver of FIG. 3;

FIG. 4B is a block diagram illustrating details of a second receiver and filter of FIG. 3;

FIG. 4C is a block diagram illustrating details of a third receiver and filter of FIG. 3;

FIG. 5 is a block diagram illustrating details of a fourth receiver of FIG. 3 that first filters the incoming signal before amplifying it;

FIG. 6A is a block diagram illustrating a first implementation of the fourth receiver of FIG. 5;

FIG. 6B is a block diagram illustrating a monopole implementation of the first implementation for the fourth receiver of FIG. 5;

FIG. 6C is a block diagram illustrating a second implementation of the fourth receiver of FIG. 5;

FIG. 6D is a block diagram illustrating a third implementation of the fourth receiver of FIG. 5;

FIG. 6E is a block diagram illustrating a fourth implementation of the fourth receiver of FIG. 5;

FIG. 6F is a block diagram illustrating a fifth implementation of the fourth receiver of FIG. 5;

FIG. 7 is a block diagram illustrating the details of the preferred embodiment for the filter of the electrostatic/electromagnetic reader of the present invention;

FIG. 8 illustrates the frequency characteristics of the receiver of FIG. 4;

FIG. 9 is a block diagram illustrating the functions blocks for transmitting data as ES and EM signals;

FIG. 10A is a block diagram illustrating details of a first switched based transmitter of FIG. 9;

FIG. 10B is a block diagram illustrating details of a second switched based transmitter of FIG. 9;

FIG. 10C is a block diagram illustrating details of a third switched based transmitter of FIG. 9;

FIG. 10D is a block diagram illustrating details of a fourth switched based transmitter of FIG. 9;

FIG. 11A is a block diagram illustrating details of a first amplifier based transmitter of FIG. 9;

FIG. 11B is a block diagram illustrating details of a second amplifier based transmitter of FIG. 9;

FIG. 11C is a block diagram illustrating details of a third amplifier based transmitter of FIG. 9;

FIG. 11D is a block diagram illustrating details of a fourth amplifier based transmitter of FIG. 9;

FIG. 11E is a block diagram illustrating details of a fifth amplifier based transmitter of FIG. 9;

FIG. 11F is a block diagram illustrating details of a sixth amplifier based transmitter of FIG. 9;

FIG. 12A is a frontal view of the electrostatic electrodes for the electrostatic/electromagnetic reader having a monopole exciter and monopole receiver;

FIG. 12B is a frontal view of the electrostatic electrodes for the electrostatic/electromagnetic reader having a dipole exciter and monopole receiver;

FIG. 13A is a circuit block diagram illustrating a monopole configured electrostatic/electromagnetic reader having a single electrostatic electrode;

FIG. 13B is a circuit block diagram illustratinga second implementation of a monopole configured electrostatic/electromagnetic reader in accordance with the present invention;

FIG. 13C is a circuit block diagram illustrating a dipole configured electrostatic/electromagnetic reader in accordance with the present invention;

FIG. 14 is a block diagram illustrating the electrostatic transceiver of the present invention;

FIG. 15 is a block diagram illustrating the electromagnetic transceiver of the present invention; and

FIG. 16 is a block diagram illustrating the combination electrostatic/electromagnetic transceiver of the present invention.

Detailed Description of the Invention

The present invention includes a method, apparatus and system for providing electric field and/or magnetic field communication utilizing either capacitance-based technology and/or induction-based technology. An advantage of the present invention is to introduce a new RFID technology in a way that is backward compatible with electromagnetic RFID systems, hence eliminating the need to have different tags for different RFID systems and/or replacing existing tags with new tags. A further advantage of the present invention is to introduce an RFID apparatus, system and method that is cost-effective, has high manufacturability, and can be easily packaged for a wide-range of applications.

In the preferred embodiment, electric field or electrostatic communication is accomplished through capacitive coupling which requires no physical contact or wires between a reader and a remotely located electric field or electrostatic transceiver. The term transceiver, as used herein, is a remote device, such as a tag or transponder, that receives and/or transmits energy (e.g., data, information, power, etc.) from/to a reader. The term reader, as used herein, is a device that transmits and/or receives energy to or from a transceiver. In addition, it will be appreciated from reading the following description that reader function may also include a writing device and/or a programmer for communicating with the transceiver.

In an electrostatic communication system, the voltage applied to capacitively-coupled plates varies in order for a charge or signal to be transmitted between a reader and an electrostatic transceiver. In general, a signal for electrostatic communication comprises an alternating electric field created between two electrodes. The transceiver needs to be in range of the reader, typically anywhere from 0.2mm to 50m, in order to have sufficient capacitive coupling to receive electrostatic signals. In contrast, electromagnetic communication is accomplished through inductive coupling, and generally has an operating range of only 3m. During transmission in the electromagnetic communication system, a current is varied in a coil in order to generate and transmit an electromagnetic field (substantially a magnetic field). Upon reception, a varying electromagnetic field is received by another coil which induces a current to flow in the coil. The current flow is converted into the received signal. As a result of the inductive coupling, the electromagnetic system requires no physical contact or wires between a reader and an

electromagnetic transceiver For purposes of the remaining discussion, the term electrostatic will be used to refer to capacitively-coupled electric fields, while the term electromagnetic will be used to refer to inductively-coupled magnetic fields. Electrostatic transceivers or readers may also be referred to as capacitively-coupled transceiver and reader devices that operate using electric field transmissions. Electromagnetic transceivers and readers may also be referred to as inductively-coupled transceiver or reader devices that operate using magnetic field transmissions. A combined electrostatic/electromagnetic transceiver may also be referred to as an ES/EM transceiver. Electrostatic signals and electromagnetic signals may be referred to as capacitively-coupled signals and inductively coupled signals, respectively.

FIG. 1A illustrates a dipole exciter and dipole receiver configuration for a preferred embodiment of a combined electrostatic and electromagnetic communication system 100. Dipole as used herein means the use of two electrodes that are not necessarily symmetrical in size or dimension. The communication system 100 includes an electrostatic/electromagnetic reader 101A, host computer system 103, and at least one of an electrostatic transceiver 102, electromagnetic transceiver 104, or an ES/EM transceiver 109.

FIG. 1B illustrates a monopole exciter and monopole receiver configuration according to the preferred embodiment of the combined electrostatic and electromagnetic communication system 100. With reference to FIG. 1B, the system 100 includes electrostatic/electromagnetic reader 101B, electrostatic transceiver 102, host computer system 103, electromagnetic transceiver 104, and an ES/EM transceiver 109.

FIG. 1C illustrates a dipole exciter and a monopole receiver of the preferred electrostatic/electromagnetic reader 101C.

FIG. 1D illustrates a system level diagram with functional sharing of an electrostatic electrode and an electromagnetic element 134, such as a coil, inductor, toroid, pot core, transformer, open magnetic structure, and the like. Dipole circuitry of the electrostatic/electromagnetic reader 101A of FIG. 1A may be modified in accordance with FIG. 1D to establish a monopole circuit by providing a return path, such as, for example, earth ground 150, common to both the reader and the electrostatic transceiver, which is lower in impedance than the coupling path of FIG. 1A between the reader and the transceiver, thereby effectively eliminating electrostatic electrodes 106, 107 and 108.

Because of the similarity and the ease of converting a dipole reader into a monopole reader, the dipole receiver and the dipole exciter reader will be described throughout except as where noted.

The reference designator 101 refers equally to 101A, 101B, 101C, and 101D. Reference to a particular reference designator 101A-101D may relate to the others depending upon the context of the statement. Electrostatic/electromagnetic reader 101A includes electrostatic electrodes 105 and 106 and electromagnetic element 134 for transmission of an excitation signal and modulated data signals on a power carrier signal by means of electrostatic and electromagnetic energy. The signals are transmitted by the reader to either an electrostatic, electromagnetic, or combination ES/EM transceiver, such as electrostatic transceiver 102, electromagnetic transceiver 104, or combination ES/EM transceiver 109. Electrostatic/electromagnetic reader 101A includes electrostatic electrodes 107 and 108 and electromagnetic element 144 for receiving data signals on a data carrier signal by means of electrostatic energy and electromagnetic energy. The data signals are transmitted by either an electrostatic, electromagnetic transceiver, or combination electrostatic/electromagnetic transceiver such as electrostatic transceiver 102, electromagnetic transceiver 104, or combination electrostatic/electromagnetic transceiver 109. Electrostatic transceiver 102 includes electrostatic electrodes 112 and 113 in order to receive and transmit electrostatic energy and signals. The electrostatic electrodes 112 and 113 may have differing shapes and be made of different materials. Some of the shapes for the electrostatic electrodes 112 and 113 include flat rectangular plates and bow tie shaped plates. In accordance with the present invention, electrostatic electrodes are not required to be balanced or symmetrical, but rather may be designed to employ various shapes, sizes and symmetries each optimized for capacitive coupling within a given application. It is further noted that a wide variety of conductive materials and compositions may be used in the construction of each electrostatic electrode. Electromagnetic transceiver 104 includes the electromagnetic element 114 in order to receive and transmit electromagnetic energy and signals. Combination electrostatic/electromagnetic transceiver 109 includes electrostatic electrodes 122 and 123 in order to receive and transmit electrostatic energy and signals the electromagnetic element 124 and capacitor 125 in order to receive and transmit electromagnetic energy and signals. The electrostatic electrodes may also be referred to as antenna, capacitor plates, contactless electrodes, wireless electrodes or

isolation electrodes. These electrostatic electrodes provide the reader and/or transceiver the ability to communicate with one another in a remote fashion. The induction coil may also be referred to as an antenna or wire-wound coil, etched coil, coil or inductor, toroid, put core. The induction coils provide the reader and/or transceiver the ability to communicate with one another in a remote fashion. Electrostatic transceiver 102 can transmit and receive information to/from the electrostatic/electromagnetic reader 101 by means of electrostatic signals and capacitive coupling. Electromagnetic transceiver 104 can transmit and receive information to/from the electrostatic/electromagnetic reader 101A by means of electromagnetic signals and induction. Combination electrostatic/electromagnetic transceiver 109 can transmit and receive information to/from the electrostatic/electromagnetic reader 101 by means of electrostatic signals and capacitive coupling or electromagnetic signals and induction. Transceivers 102, 104 and 109 may be passive or active devices in that they may include an internal power supply to provide additional functionality and increased read range to a reader. Host computer 103 is coupled to the electrostatic/electromagnetic reader 101 and may couple to other electrostatic/electromagnetic readers, electromagnetic readers or electrostatic readers (not shown in FIGS. 1A-1D) in order to have other points of communication.

An electrostatic transceiver 102 and electromagnetic transceiver 104 could be combined to form an electrostatic/electromagnetic transceiver by including the electrostatic electrodes 112 and 113 of the electrostatic transceiver 104 without using a combined electrostatic/electromagnetic reader 101. This is illustrated by electrostatic/electromagnetic transceiver 109. While this would avoid the replacement of electromagnetic readers with electrostatic/electromagnetic reader 101, this would require greater investment by requiring the replacement of the electromagnetic transceivers 104 within the combined electrostatic and electromagnetic communication system in order to be compatible with electromagnetic and electrostatic communications. It is better to combine the electromagnetic and electrostatic technology into a reader, replacing current electromagnetic only reader with the combined electrostatic/electromagnetic readers 101, in order to be compatible with both electrostatic and electromagnetic communication technology. In this manner, electromagnetic transceivers need not be replaced and new electrostatic transceivers can be introduced into the communication system having electrostatic/electromagnetic readers 101. It costs less to replace the electromagnetic

readers with electrostatic/electromagnetic readers than it does to replace a large number of electromagnetic transceivers.

Thus, the electrostatic/electromagnetic reader 101 includes an induction coil and electrostatic electrodes in order to provide the combined electrostatic and electromagnetic communication. In order to combine the functionality of the induction coil and the electrostatic electrodes together into a single reader, the proper design is necessary to efficiently combine the functionality in a single electrostatic/electromagnetic reader 101. A problem with combining the functionality is that the desired input impedance may be different for receiving electrostatic signals than it is for electromagnetic signals. The desired input impedance for a receiver receiving electromagnetic signals from a coil is usually a low impedance. The desired input impedance for a receiver receiving electrostatic signals from an electrostatic electrode is usually a high impedance. Another problem is that the desired operation of the transmitters is different. In order to transmit signals through a coil, it is desirable to have large AC current flows through the coil. In order to transmit signals through an electrostatic electrode or electrodes, it is desirable to have large AC voltage swings on the electrostatic electrode or electrodes.

FIG. 2 illustrates a block diagram of the electrostatic/electromagnetic reader 101 of the present invention in a dipole electrostatic configuration. The electrostatic/electromagnetic reader 101A may be configured in a monopole electrostatic configuration, as illustrated by FIG. 1B, by connecting one of the electrostatic electrodes to earth ground 150 effectively eliminating it as an electrode, as later shown in association with FIG. 13A and 13B. Circuitry within the reader that connects to the electrostatic electrode that is grounded may be simplified or eliminated when not used. In a monopole configuration, earth ground 150 is part of the return path. Accordingly, exciter 201 and receiver 202 in reader 101B have a connection to earth ground 150 in the monopole configuration. In the dipole configuration neither electrostatic electrode has a connection to earth ground 150. The dipole configuration lends itself to a more portable system but one could easily connect an electrode to a ground reference of some sort thereby having a portable monopole system.

The electrostatic/electromagnetic reader 101A includes circuits such as an exciter 201, a receiver 202, a demodulator 203, a processor 204, the electrostatic electrodes 105-108, and the electromagnetic induction coils 134 and 144. Additional circuitry may

include, without limitation, a memory, a modulator, a filter, a digital signal processor, a signal source, a gain stage, a gain control stage(s), power supply regulation, circuit protection, electromagnetic interference suppression, and logic. The processor 204 couples to the host computer 103 over a host interface to bi-directionally transfer information, couples to the exciter 201 to supply a clock and transfer information, and couples to the demodulator 203 to receive information. In accordance with the present invention, processor 204 may be a microprocessor or microcomputer as is known in the art. In addition, processor 204 may comprise memory and/or associated logic circuitry. The demodulator 203 is a signal demodulator and may simply be a detector such as a comparator or a simple CMOS inverter with the desired threshold characteristics. Exciter 201 couples to the processor 204 to receive information and couples to the electrostatic electrodes 105-106 and the electromagnetic element134 to transmit signals (and information) as electrostatic or electromagnetic signals respectively. Receiver 202 couples to the electrostatic electrodes 107-108 and the electromagnetic element144 to receive electrostatic and electromagnetic signals and information respectively and couples to the demodulator 203 to transfer signals and information. Demodulator 203 couples to the receiver 202 to receive signals and information and couples to the processor 204 for transferring information. Electrostatic electrodes 105-108 may take on various forms including flat conductive plates, conductive fringe, conductive wires, or conductive strips. Induction coils 134 and 144 may have various forms including a wire loop or loops, wire wound coils, or looped etched metal strips. Transmit block 211 includes the essential elements for combining the transmitting of electrostatic and electromagnetic signals. Receive block 212 includes the essential elements for combining the receiving of electrostatic and electromagnetic signals.

In general, electrostatic/electromagnetic reader 101 generates an electrostatic (electric) field for use both as a power source for the electrostatic transceiver 102 and the ES/EM transceiver 109 for transferring information between reader 101 and transceivers 102 or 109 by using electrostatic signals. As such, electrostatic reader 101 electrostatically generates and transmits an excitation signal through the nearbyair, gas, liquid, or atmosphere via the reader's electrostatic electrodes, except for the return path in a monopole system. The electrostatic/electromagnetic reader 101 generates an electromagnetic field for use both as a power source for the electromagnetic transceiver

104 and the ES/EM transceiver 109 for transferring information between reader 101 and transceivers 104 or 109 by using electromagnetic signals. The excitation signal is an AC signal which activates electrostatic transceiver 102 or transceiver 109 when they come within the capacitance coupling range of reader 101. The excitation signal may also activate electromagnetic transceiver 104 or transceiver 109 when they come within the inductive coupling range of reader 101. Upon being sufficiently energized, the transceivers 102, 104, or 109 may respond by transmitting a read data signal carrying the information stored in their memory. In accordance to the present invention, reader 101 may also provide a write signal to communicate and write information to the transceivers 102, 104 or 109 as part of a write operation. It is to be appreciated that the excitation signal must be generated and transmitted by reader 101 to energize a passive transceiver (i.e. without an internal energy source). The excitation signal is an AC energy source and can be a continuous waveform or a varying waveform (i.e. amplitude, frequency, time, etc. of the waveform may vary). The reader 101 usually has available a larger power source than the transceivers. Thus, the reader 101 has very sensitive receiving and high energy transmission when compared with the transceivers.

FIG. 3 is the receive block 212 illustrating the functions blocks for receiving ES and EM signals. The receive block 212 includes the receive/amplify block 302, the filtering block 304, the detection block 306, and the demodulation block 308. The receive/amplify block 302 basically provides for the interface to the electrostatic electrodes 107-108 and the electromagnetic element144. It further provides the initial amplification and in some cases may perform preliminary filtering as well in order to avoid amplifying a wide frequency band of signals when only a narrow band is desired. The filtering block 304 provides for removing unwanted signals in certain rejection frequency bands and emphasizing the desired signals in a certain pass band or bands. The filtering block 304 may be implemented in many ways including as analog filters or as digital filters. The detection block 306 is provided for the analog filter types of the filtering block 304. The detection block 306 detects the desired data signal from the carrier frequency signal and generates a serial data stream, demodulating the data from the carrier. The detector block 306 may be a comparator that compares the input signal to a threshold or it may simply be an inverter or buffer, preferably a CMOS inverter or buffer, that detects the signal at certain threshold levels. For digital filter types, the detection

block 306 is not needed as its function may be replaced with sample and hold elements in conjunction with analog to digital converters. The demodulation block 308 is for receiving the data stream in whatever form and decoding or demodulating the actual information from the received data stream. The demodulation block 308 is performed by the processor 204 in the ES/EM reader 101. There are various ways of combining these functional blocks and implementing the functional blocks in order to provide the capability of receiving both electrostatic and electromagnetic signals. Following is a description of various implementations of the receive block 212.

FIG. 4A illustrates details of a summing receiver/amplifier 302A within the receive block 212. The summing receiver/amplifier 302A includes an electrostatic signal amplifier 322, an electromagnetic signal amplifier 324, and an analog summer 326. The ES signal amplifier 322 is preferably a high input impedance amplifier for receiving electrostatic signals. Resistors 327 and 328, having a high resistance value on the order of one mega-ohm each, are coupled between the two respective inputs of the amplifier 322 and ground in order to provide a ground reference and keep the input into the amplifier from floating. The EM signal amplifier 324 is preferably a low input impedance amplifier for receiving electromagnetic signals. The outputs from the respective amplifiers 322 and 324 on nodes 323 and 325 respectively, are input into the analog summer 326. The analog summer 326 combines the analog signals on nodes 323 and 325 accordingly generating one signal output 311. The output 311 of the summing receiver/amplifier 302A is then coupled to the filtering block 304 for further processing.

In an alternative to FIG. 4A, it will be appreciated by those skilled in the art that the electrostatic and electromagnetic antennas and their associated terminations could be combined through a switch (not shown). In this circumstance, amplifier 324 and analog summer 326 may be eliminated, thereby simplifying the circuit of FIG. 4A. The switch (not shown) may be multiplexed between the electrostatic antennas 107, 108 and the electromagnetic element 144 and their respective terminations, at a fixed duty cycle. In this alternative, the duty cycle may be controlled via logic (not shown) or a microprocessor (not shown). In this alternative embodiment, the input amplifier 322 may include a detection device (not shown), such as a received signal strength indicator (RSSI). When a tag is brought into the field (electric or magnetic), the RSSI will rise due to the presence of the data carrier. As the signal exceeds a predetermined threshold, the switch

commutation will stop and the tag data will be received by the reader 101. The switch will then resume commutation. The relative frequency of tag types presented to the reader may be analyzed by the microprocessor. The duty cycle may then be adjusted to favor the tag type that predominates in the environment.

FIG. 4B illustrates the details of a first digital filtering method for combining electromagnetic and electrostatic signals. The dual digital receiver/amplifier 302B includes an electrostatic signal amplifier 322, an electromagnetic signal amplifier 324, and a first sample and hold 332, a second sample and hold 334, a first analog to digital converter 336, and a second analog to digital converter 338. The ES signal amplifier 322 is preferably a high input impedance amplifier for receiving electrostatic signals. Resistors 327 and 328, having a high resistance value on the order of one mega-ohm each, are coupled between the two respective inputs of the amplifier 322 and ground in order to provide a ground reference and keep the input into the amplifier from floating. The EM signal amplifier 324 is preferably a low input impedance amplifier for receiving electromagnetic signals. The outputs from the respective amplifiers 322 and 324 on nodes 323 and 325 respectively, are input into the sample and hold 332 and the sample and hold 334. The sample and holds 332 and 334 are sample and hold circuits that sample the analog signals at their respective inputs and hold the samples for conversion by analog to digital converters. The clock frequencies of the sample and hold circuits is at least twice the rate of the frequency expected on the input signals to comply with the Nyquist sampling theory. The analog to digital converters 336 and 338 convert the analog signals that are respectively input into digital signals that may be sent to the digital signal processor (DSP) that implements the digital filter 304A. The digital filter 304A performs the desired filtering function but in the digital domain. The output 317 from the digital filter 304A is provided to the demodulation block 308.

FIG. 4C illustrates the details of a second digital filtering method for combining electromagnetic and electrostatic signals. The single digital receiver/amplifier 302C includes an electrostatic signal amplifier 322, an electromagnetic signal amplifier 324, an analog multiplexor or a summer 342, a sample and hold 344, an analog to digital converter 346. The ES signal amplifier 322 is preferably a high input impedance amplifier for receiving electrostatic signals. Resistors 327 and 328, having a high resistance value on the order of one mega-ohm each, are coupled between the two respective inputs of the

amplifier 322 and ground in order to provide a ground reference and keep the input into the amplifier from floating. The EM signal amplifier 324 is preferably a low input impedance amplifier for receiving electromagnetic signals. The outputs from the respective amplifiers 322 and 324 on nodes 323 and 325 respectively, are input into the analog multiplexor 342. The output from the analog multiplexor 342 is coupled to the sample and hold 344. The sample and hold 344 is a sample and hold circuit that samples the analog signals at its input and holds the samples for conversion by an analog to digital converter. The clock frequencies of the sample and hold circuit is at least twice the rate of the frequency expected on the input signals to comply with the Nyquist sampling theory. The analog to digital converter 346 converts the analog signals that are at its input on node 345 into digital signals that may be sent to the digital signal processor (DSP) that implements the digital filter 304B. The digital filter 304B performs the desired filtering function but in the digital domain. The output 317 from the digital filter 304B is provided to the demodulation block 308.

FIG. 5 is a block diagram illustrating details of the pre-filtered receiver/amplifier 302D. The pre-filtered receiver/amplifier 302D first filters the incoming signal before amplifying it. The pre-filtered receiver/amplifier 302D includes the filtering block 502 and the high impedance amplifier 322 previously used for only receiving ES signals. At first glance it seems that the EM coil 144 for receiving EM signals is absent. However, this is not the case because coils in a filter can receive the electromagnetic signals. In filtering block 502 coil inductors and capacitors are used, whereby one or more of the coil inductors may receive the EM signals. Various implementations of the filtering block 502 are more fully described with reference to FIG. 6A through FIG. 6D.

FIG. 6A is a block diagram illustrating a dipole version of the pre-filtered receiver/amplifier 302E. The pre-filtered receiver/amplifier 302E includes the filtering block 502A and the high input impedance amplifier 322. Filtering block 502A includes two parallel LC circuits 602A and 602B each coupled respectively to an electrostatic electrode 107 and 108 on nodes 621 and 622 at one end and to ground at another end to provide bandpass filtering. The resonant circuit of the inductive coil 614 in parallel with the capacitor 612, provides a high impedance path for signals at the desired pass frequency such that they pass through to the amplifier while for receiving electromagnetic signals, the coils 614 act as antennas and resonate with the capacitors 612 to generate opposing

voltages at nodes 621 and 622. Resistors 327 and 328, having a high resistance value on the order of one mega-ohm each, are coupled between the two respective inputs 621 and 622 of the amplifier 322 and ground in order to provide a ground reference and keep the input into the amplifier from floating. Note that for a dipole receiver, the coils 614 in the parallel LC circuits need to be physically oriented one-hundred-eighty degrees from each other so that the voltages at nodes 621 and 622 are opposite. This holds true for other dipole receivers with similar circuitry. In the monopole case one of the inputs into the amplifier are connected to an earth ground reference or another reference voltage source. The pass frequency is preferably the data carrier frequency. Coil 614 may be further enhanced to increase the efficiency of receiving electromagnetic signals by providing a portion of it external to any shielding that might otherwise be present.

FIG. 6B is a block diagram illustrating a monopole version of the pre-filtered receiver/amplifier 302F. The pre-filtered receiver/amplifier 302F includes the filtering block 502B and the high input impedance amplifier 322 previously used for only receiving ES signals. Filtering block 502B includes the parallel LC circuit 602C coupled respectively to electrostatic electrode 108 at one end and ground at another end to provide band-pass filtering. Resistor 328, having a high resistance value on the order of one mega-ohm, is coupled between input 622 of the amplifier 322 and ground in order to provide a ground reference and keep the input into the amplifier from floating. The resonant circuit of the inductive coil 614 in parallel with the capacitor 612, provides a high impedance path for signals at the desired pass frequency such that they pass through to the amplifier. Coil 614 acts as an antenna and resonates with the capacitor 612 to amplify the data carrier frequency. This exemplifies the monopole case where one of the inputs into the amplifier are connected to an earth ground reference or another reference voltage source. The pass frequency is preferably the data carrier frequency. Coil 614 may be further enhanced to increase the efficiency of receiving electromagnetic signals by providing a portion of it external to any shielding that might otherwise be present.

FIG. 6C is a block diagram illustrating a dipole version of the pre-filtered receiver/amplifier 302G. The pre-filtered receiver/amplifier 302G includes the filtering block 502C and the high input impedance amplifier 322 previously used for only receiving ES signals. Filtering block 502C includes two band-pass filters at each electrostatic electrode 107 and 108. Parallel LC circuits 602D and 602E are each coupled respectively

to an electrostatic electrode 107 and 108 on nodes 633 and 634 at one end and ground at another end to provide band-pass filtering. Series LC circuits 604A and 604B are respectively coupled in series between the amplifier 322 and the electrostatic electrodes 107 and 108 to further provide band-pass filtering. Resistors 627 and 628, having a high resistance value on the order of one mega-ohm each, are coupled between the two respective inputs 631 and 632 of the amplifier 322 and ground in order to provide a ground reference and keep the input into the amplifier from floating. The resonant circuit in parallel LC circuit 602D and 602E, provides a high impedance path for signals at the desired pass frequency such that they pass through to the series LC circuits 604A and 604B the coils 614 act as antennas and resonate with the capacitors 612 to generate opposing voltages at nodes 631 and 632. Note that for a dipole receiver, the coils 614 in the parallel LC circuits or coils 618 in the series resonant circuits need to be physically oriented one-hundred-eighty degrees from each other so that the voltages at nodes 631 and 632 are opposite. This holds true for other dipole receivers with similar circuitry. In the monopole case one of the inputs into the amplifier are connected to an earth ground reference or another reference voltage source. The pass frequency is preferably the data carrier frequency. The resonant circuit in series LC circuit 604A and 604B, provides a low impedance path for signals at the desired pass frequency such that they pass through the series LC circuits 604A and 604B and into the amplifier 322. The pass frequency of the series LC circuits 604A and 604B is preferably the data carrier frequency.

FIG. 6D is a block diagram illustrating a dipole version of the pre-filtered receiver/amplifier 302H for a third implementation of the fourth receiver of FIG. 5. The pre-filtered receiver/amplifier 302H includes the filtering block 502D and the high input impedance amplifier 322 previously used for only receiving ES signals. Filtering block 502D includes two band-pass filters at each electrostatic electrode 107 and 108. Series LC circuits 604C and 604D are respectively coupled in series between the electrostatic electrodes 107 and 108 and the amplifier 322 to provide band-pass filtering. The resonant circuit, in series LC circuit 604C and 604D, provides a low impedance path for signals at the desired pass frequency such that they pass through the series LC circuits 604C and 604D and into the amplifier 322. Parallel LC circuits 602F and 602G are each coupled respectively to nodes 641 and 642 at one end and ground at another end to provide band-pass filtering. The resonant circuit, in parallel LC circuit 602F and 602G, provides a high

impedance path for signals at the desired pass frequency such that they pass through to the amplifier 322. The pass frequency in each case of the series LC circuits and parallel LC circuits is preferably the data carrier frequency. For receiving electromagnetic signals the coils 614 act as antennas and resonate with the capacitors 612 to generate opposing voltages at nodes 641 and 642. Note that for a dipole receiver, the coils 614 in the parallel LC circuits or coils 618 in the series resonant circuits need to be physically oriented one-hundred-eighty degrees from each other so that the voltages at nodes 641 and 642 are opposite. This holds true for other dipole receivers with similar circuitry. In the monopole case one of the inputs into the amplifier are connected to an earth ground reference or another reference voltage source. The pass frequency of the series LC circuits 604A and 604B is preferably the data carrier frequency.

FIG. 6E is a block diagram illustrating a dipole version of the pre-filtered receiver/amplifier 302I for a fourth implementation of the fourth receiver of FIG. 5. The pre-filtered receiver/amplifier 302I includes the filtering block 502E and the high impedance amplifier 322. Filtering block 502E includes two band-pass filters and two notch filters between each electrostatic electrode 107 and 108 and the amplifier 322. Resistors 327 and 328, having a high resistance value on the order of one mega-ohm each, are coupled between the two respective inputs 633 and 634 of the notch filters (parallel LC circuits 602H and 602J) and ground in order to provide a ground reference and keep the inputs from floating. Resistors 627 and 628, having a high resistance value on the order of one mega-ohm each, are coupled between the two respective inputs 631 and 632 of the amplifier 322 and ground in order to provide a ground reference and keep the inputs into the amplifier from floating so as to reduce noise. Parallel LC circuits 602H and 602J are each coupled respectively to the electrostatic electrode 107 and 108 on nodes 633 and 634 at one end and the series LC circuits 604E and 604F at nodes 653 and 654 to provide notch filtering. The resonant circuit in parallel LC circuit 602H and 602J, provides a high impedance path for signals at the desired notch frequency such that they are greatly attenuated before reaching the series LC circuits 604E and 604F. The preferred notch frequency is at the power carrier frequency or exciter frequency which is preferably 125 kHz. Series LC circuits 604E and 604F are respectively coupled in series between the amplifier 322 and the parallel LC circuits 602H and 602J to provide band-pass filtering. The resonant circuit in series LC circuit 604E and 604F, provides a low impedance path

for signals at the desired pass frequency such that they pass through the series LC circuits 604E and 604F and into the amplifier 322. Note that for a dipole receiver, the coils 614 in the parallel LC circuit or coils 618 in series need to be physically oriented one-hundred-eighty degrees from each other so that the voltages at nodes 631 and 632 are opposite. This holds true for other dipole receivers with similar circuitry. In the monopole case one of the inputs into the amplifier are connected to an earth ground reference or another reference voltage source. The pass frequency of the series LC circuits 604E and 604F is preferably the data carrier frequency.

FIG. 6F illustrates details of a high impedance receiver/amplifier 302J. The high impedance receiver/amplifier 302J includes a high input impedance amplifier 322 and a high input impedance filtering block 502F. The amplifier 322 is preferably a high input impedance amplifier for receiving electrostatic signals. The outputs from the amplifier 322 on node 661 is input into the detector 306. The output 317 of the detector 306 is then coupled to the demodulation block 308 for further processing. The high impedance filtering block pre-filters the data signals before reaching the amplifier and includes all necessary filtering otherwise provided by filtering block 304. It is believed that the extra filtering on the front end of the receiver improves the sensitivity and enhances the ability to receive electromagnetic signals. Electromagnetic signals are typically composed of a substantial magnetic field signal with a small electric field component. Electrostatic signals are typically composed of a substantial electric field signal with a small magnetic field component while in other cases there may be no magnetic field component. If the high impedance receiver/amplifier 302J is operating in a combined system and the transceiver 104 is communicating using electromagnetic signals, there is an electric field component to the electromagnetic signal which is possible to detect by a sensitive high input impedance receiver such as 302J. The electrostatic electrodes 107 and 108 may receive the electric component of the electromagnetic signals from an electromagnetic transceiver.

FIG. 7 is a block diagram of the preferred embodiment of the filter 304C within the electrostatic/electromagnetic reader 101 of the present invention. A gain amplifier 700 initially amplifies a signal received from the receive/amplify block 700 on node 311. A first notch filter 701 or band rejection filter having a first notch frequency receives signals from the output of the gain amplifier 700. The first notch frequency is 125 kHz in the

preferred embodiment. A first band-pass filter 704 having a first pass frequency is coupled to the first notch filter 701 to receive signals. The first pass frequency is 62.5 kHz in the preferred embodiment. The first band-pass filter 704 is preferably an active filter and provides gain to the input signal. A second notch filter 702 or band rejection filter having a second notch frequency is coupled to the first band-pass filter 704 to receive signals. The second notch frequency is 125 kHz in the preferred embodiment. A second band-pass filter 704 having a second pass frequency is coupled to the second notch filter 702 to receive signals. The second pass frequency is 62.5 kHz in the preferred embodiment. The second band-pass filter 705 is an active filter and provides gain to the input signal. A third notch filter 703 or band rejection filter having a third notch frequency is coupled to the second band-pass filter 705 to receive signals. The third notch frequency is 250 kHz in the preferred embodiment. The third notch filter provides the final output 317 of the filtering block 304 of the preferred embodiment to the detection block 306. Notch filters 701-703 and band-pass filters 704-705 may be implemented using passive RLC components or active components with the passive components such as operational amplifiers or transistor amplifiers. Filtering stages are implemented as required.

FIG. 8 is a filter response diagram illustrating the desired frequency characteristics 800 of the filter 304C where amplitude 802 is plotted logarithmically against frequency 801 which is plotted logarithmically. The amplitude of the receiver response is zero decibels at reference designator 805.. At the preferred carrier frequency 810 (i.e., 62.5 kHz) for transmission by the transceivers 102, 104, and 109 the receiver response 803 has a gain in amplitude to amplitude 804. At the transmission frequencies 811 and second harmonic 812 of the reader (i.e., 125 kHz, 250 kHz), receiver response 803 has losses in amplitude to amplitudes 806 and 807 respectively. In this manner the receiver accepts signals at the carrier frequency and amplifies them while rejecting signals at the transmission frequencies of the reader 101 by providing losses so that the signals at the carrier frequency are enhanced for demodulation by the demodulator 203.

Receiver sensitivity (i.e., gain at the carrier frequency of the transceivers 102, 104 and 109 with loss or no gain at others) of the electrostatic/electromagnetic reader 101 is important in the combined electrostatic and electromagnetic communication system because signals transmitted by the electrostatic transceiver 102, the electromagnetic

transceiver 104 and the combined electrostatic/electromagnetic transceiver 109 are relatively low in energy when compared with the signals transmitted by the reader 101. The reader 101 can usually provide the higher energy transmission because it has available a larger power source than the transceivers 102, 104 and 109 and electrostatic signals tend to require a high voltage amplitude signal. Furthermore the circuit area available to the reader 101 is significantly greater than that of the tag or transceiver 102, 104, or 109. The power available to the reader also provides flexibility in the design of the receiver and the selection of gain stages.

FIG. 9 illustrates the functionality of the transmit block 211 for transmitting data as ES and EM signals. The transmit block 211 includes the modulation block 902 and the transmit/amplify block 904. The modulation block 902 generates a periodic signal which it then modifies in amplitude, frequency, and/or phase to carry information which can be understood by transceiver 102, 104 or 109. The modulation or encoding of the data prior to transmission is usually performed by the processor 204. The transmit/amplify block 904 accepts the data stream on node 913 and provides for the amplification and transmission of ES and EM signals. The transmit/amplify block 904 in an active shunt option also provides for the combining of circuitry to support both the electromagnetic element134 and the electrostatic electrodes 105-106. There are various ways of combining circuitry and implementing the functional blocks in order to provide the capability of transmitting both electrostatic and electromagnetic signals. Following is a description of various implementations of the transmit block 211. FIG. 10A through FIG. 10D illustrate a switch implementation while FIG. 11A through FIG. 11E illustrate an active driver implementation of the transmit block 211. In order to transmit EM signals, the EM coil is preferably provided with a changing current. In order to transmit ES signals, ES electrodes are preferably provided with large AC voltage swings.

FIG. 10A is a block diagram illustrating details of a switched parallel resonant dipole transmitter 904A. Data from a source such as the host 103 is provided to the processor 204 for modulation block 902. The output of the modulation is provided on signal line 913 and is input into the transmitter 904A. Transmitter 904A includes the switch 1010A, a transformer 1001, and capacitor 1014. Transformer 1001 has two windings, coil 1012 being the primary winding and EM coil 134 being the secondary winding. The transmitter 904A is in a dipole configuration with the two electrostatic

electrodes 105 and 106. The EM coil 134 of the transformer 1001 is for transmitting EM signals and is in a parallel resonant circuit with capacitor 1014. Coil 1012 is coupled to the high level supply voltage (VDD) at one end and the switch 1010A at the other. As switch 1010A opens and closes in accordance with the clock and data stream on node 913 from the modulation block 902, current is caused to flow through coil 1012 which is inductively coupled to the EM coil 134 causing EM signals to be transmitted. Across the transformer there is a step up in voltage such that increased voltage levels over and above the high level supply voltage is provided to the ES electrodes 105-106 causing ES signals to be transmitted. In order to improve modulation control, a switch 1015 may be connected between nodes 1005 and 1006 to selectively short them together in response to a host modulation control signal 1016 and terminate signal radiation from the electrostatic electrodes 105 and 106 and EM coil 134. Switch 1010A includes a flyback diode 1013 for protecting it from damage from excessive voltage applied across its terminals in an open condition. Flyback diode 1013 has anode coupled to the ground side of the switch 1010A and a cathode coupled to the switch terminal that couples to the coil 1012 at node 1011. Alternatively, a flyback diode could have been coupled across coil 1012 as illustrated in FIG. 10B. Resistor 1017, having a high resistance value on the order of one mega-ohm, is coupled between the node 1006 and ground in order to provide a ground reference and keep the output from the electrostatic electrode 106 from floating. Resistor 107 may alternatively be connected at a center tap of coil 134 for a balanced voltage across electrodes 105 and 106. Switch 1010A may be alternatively implemented by semiconductor devices such as field effect transistors 1010B or bipolar transistors 1010C. If noise emission is not a problem, capacitor 1014 may be eliminated in which case the switching harmonics may be transmitted through the electrostatic electrodes.

FIG. 10B is a block diagram illustrating a switched parallel resonant monopole transmitter 904B of the preferred embodiment. The monopole transmitter 904B has the same components as the dipole transmitter 904A but has one leg of the parallel resonant circuit, coil 1012 and capacitor 1014, attached to earth ground 150 thereby eliminating the electrostatic electrode 106 of FIG 10A. In order to improve modulation control, a switch 1015 may be connected between node 1005 and ground to selectively short node 1005 to ground in response to a host modulation control signal 1016 and terminate signal radiation from the electrostatic electrode 105 and EM coil 134. Coil 1012 includes a flyback diode

1023 across its two terminals with an anode coupled to node 1021 and a cathode coupled to the high level supply voltage. The flyback diode 1023 across coil 1012 is to protect the switch 1020A from excessive voltage levels when open. Alternatively, a flyback diode 1013 could have been incorporated into the switch 1020A as is illustrated in FIG. 10A. Switch 1020A can be alternatively implemented by field effect transistor 1020B or bipolar transistor 1020C. EM signals emanate from the coil 134 while ES signals emanate from the electrostatic electrode 105.

FIG. 10C is a block diagram illustrating a switched series resonant transmitter 904C. EM coil 134 and capacitor 1034 are a series resonant circuit. ES electrode 105 couples to the midpoint of the series resonant circuit at node 1032 so that it may experience the larger voltage swings. Switch 1010A causes current to flow through the series resonant circuit when it opens and closes so that an EM signal may emanate from the EM coil 134 and an ES signal can emanate from the ES electrode 105 with ES electrode 106 being a reference to ground. In order to improved modulation control, a switch 1015 may be connected between node 1005 and ground to selectively short node 1005 to ground in response to a host modulation control signal 1016 and terminate signal radiation from the electrostatic electrode 105 and EM coil 134. Switch 1010A can be alternatively implemented by field effect transistor 1010B or bipolar transistor 1010C.

FIG. 10D is a block diagram illustrating a simpler implementation of FIG. 10A. In comparison with FIG. 10A, the transmitter 904L has capacitor 1014 eliminated in comparison with transmitter 904A. Transmitter 904L is a non-resonant transmitter in that sufficient voltage levels are provided across coil 1012 without the need of a resonant tank circuit when switch 1020A is open and closed. The transformer ratio or step up (1:N) across the transformer 1001 from coil 1012 to coil 134 is appropriately selected to provide sufficient voltage levels across transformer coil 134 for radiating electrostatic and electromagnetic signals. In this case, modulation block 902 provides a sinusoidal modulation signal on node 913 to the driver 1121. To improve modulation control, a switch 1015 may be connected between nodes 1005 and 1006 to selectively short them together in response to a host modulation control signal 1016 and terminate signal radiation from the electrostatic electrodes 105 and 106 and EM coil 134. Resistor 1017, having a high resistance value on the order of one mega-ohm, is coupled between the node 1006 and ground in order to provide a ground reference and keep the output from the

electrostatic electrode 106 from floating. Resistor 1017 may alternatively be connected at a center tap of coil 134 for a balanced voltage across electrodes 105 and 106. One advantage to a non-resonant transmitter is that multiple carrier frequencies can be used not just certain carrier frequencies where resonance occurs to create large voltage amplitudes across the electrostatic electrodes 105 and 106 and EM coil 134. Thus, a non-resonant transmitter, such as transmitter 904L, can support frequency hopping from one carrier frequency to another.

FIG. 11A is a block diagram illustrating an active drive parallel resonant dipole transmitter 904D. The transmitter 904D includes the active driver 1101, the transformer 1001 having a first winding 134 and a second winding 1012, and a capacitor 1014. The parallel resonant circuit consists of the coil 1012 and the capacitor 1014. Transmitter 904D is analogous to the transmitter 904A of FIG. 10A. Driver 1101 actively drives node 1103 in response to data signals on node 913. Because the coil 134 wants to avoid sudden current changes, when the driver starts supplying a drive signal it increases the voltage across the transformer 1001. Active drivers, analog or digital, may be preferable over a switch for several reasons. If standard CMOS digital logic gates are used as the active drivers, they are easy to implement and may be inexpensive in that spare gates may be available for such use. Additionally, the complementary output associated with a CMOS driver provides faster switching speeds and thus may operate over a wider bandwidth than a switch implementation. An analog driver may be preferable over a switch implementation because it can generate purer sine waves at its output and therefore generate less RFI/EMI emissions. Although an analog driver may require a heat sink, it may not require any ferrite elements at its output to lower emissions where another type of driver might. EM signals emanate from the coil 134 while ES signals emanate from the electrostatic electrodes 105 and 106. Transmitter 904D includes resistor 1117, having a high resistance value on the order of one mega-ohm, coupled between the node 1106 and ground in order to provide a ground reference and keep the output from the electrostatic electrode 106 from floating. Resistor 1117 may alternatively be connected at a center tap of coil 134 for a balanced voltage across electrodes 105 and 106. In order to improved modulation control, a switch 1015 may be connected between nodes 1105 and 1106 to selectively short them together in response to a host modulation control signal 1016 and terminate signal radiation from the electrostatic electrodes 105 and 106 and EM coil 134.

FIG. 11B is a block diagram illustrating a push-pull driver transmitter 904E. The push-pull driver transmitter 904E includes a first driver 1111, an inverter 1112, a second driver 1113, transformer 1001 having a first coil 134 and a second coil 1012, an optional capacitor 1014. The coil 1012 and the capacitor 1014 create a parallel resonant circuit. Data signals from the modulation block on node 913 are coupled to the driver 1111 and the inverter 1112. The output of the inverter 1112 is coupled to the input of the second driver 1113. In this manner the first driver 1111 and the second driver 1111 are nearly one-hundred eighty degrees out of phase. When the out of phase signals are applied to the coil 134, nearly twice the voltage is generated across coil 134. The voltage generated across the coil 134 is stepped up by the step up transformer 1001 and supplied to the ES electrodes 105 and 106. EM signals emanate from the coil 134 while ES signals emanate from the electrostatic electrodes 105 and 106. Transmitter 904E includes resistor 1117, having a high resistance value on the order of one mega-ohm, coupled between the node 1106 and ground in order to provide a ground reference and keep the output from the electrostatic electrode 106 from floating. Resistor 1117 may alternatively be connected at a center tap of coil 134 for a balanced voltage across electrodes 105 and 106. In order to improve modulation control, a switch 1015 may be connected between nodes 1105 and 1106 to selectively short them together in response to a host modulation control signal 1016 and terminate signal radiation from the electrostatic electrodes 105 and 106 and EM coil 134.

FIG. 11C is a block diagram illustrating an active series resonant transformer dipole transmitter 904F. Transmitter 904F includes the driver 1121, the transformer 1001 having a first winding consisting of coil 134 and a second winding made of coil 1012, and a capacitor 1104. Capacitor 1104 and coil 1012, in series with one another, make up a series resonant circuit preferably designed to be resonant at the exciter or power carrier frequency. Voltage across the coil 1012 is stepped up by the transformer 1001 to coil 134 so that relatively large voltage swings may be applied to the electrostatic electrodes 105-106. Driver 1121 actively drives signals into the series resonant circuit. EM signals emanate from the coil 134 while ES signals emanate from the electrostatic electrodes 105 and 106. Transmitter 904F includes resistor 1117, having a high resistance value on the order of one mega-ohm, coupled between the node 1106 and ground in order to provide a ground reference and keep the output from the electrostatic electrode 106 from floating.

Resistor 1117 may alternatively be connected at a center tap of coil 134 for a balanced voltage across electrodes 105 and 106. In order to improve modulation control, a switch 1015 may be connected between nodes 1105 and 1106 to selectively short them together in response to a host modulation control signal 1016 and terminate signal radiation from the electrostatic electrodes 105 and 106 and EM coil 134.

FIG. 11D is a block diagram illustrating an active series resonant transformer monopole transmitter 904G. Transmitter 904G is very similar to transmitter 904F except having one of the electrostatic electrodes coupled to the midpoint of the series resonant circuit. Transmitter 904G includes the driver 1121, the transformer 1001 having a first winding consisting of coil 1012 and a second winding made of coil 134, and a capacitor 1104 coupled in series to ground at one end and terminals of coil 134 and the coil 1012 at an opposite end. Capacitor 1114 and coil 1012, in series with one another, make up a series resonant circuit preferably designed to be resonant at the exciter or power carrier frequency. Voltage across the coil 134 is stepped up by the transformer 1001 and also the voltage on node 1124 generated by the series resonant coil 1012 and capacitor 1114 is summed with the voltage induced across the secondary coil 134 to generate a higher voltage at the electrostatic electrode 105. Driver 1121 actively drives signals into the series resonant circuit. EM signals emanate from the coil 134 while ES signals emanate from the electrostatic electrode 105. In order to improved modulation control, a switch 1015 may be connected between node 1123 and ground to selectively short node 1123 to ground in response to a host modulation control signal 1016 and terminate signal radiation from the electrostatic electrode 105 and EM coil 134.

FIG. 11E is a block diagram illustrating a simpler implementation of FIG. 11D. Transmitter 904H is very similar to transmitter 904G except that the connection on the coil 134 is now at ground, when it was previously connected at node 1124 adding the resonant voltage to node 1123. Transmitter 904H includes the driver 1121, the transformer 1001 having a first winding consisting of coil 1012 and a second winding made of coil 134, and a capacitor 1114 in series to ground with the coil 1012. Coil 134 is coupled to ES electrode 105 at node 1123 at one end and ground at the opposite end. Capacitor 1114 and coil 1012, in series with one another, make up a series resonant circuit preferably designed to be resonant at the exciter or power carrier frequency. Voltage across the coil 134 is stepped up by the transformer 1001 so that relatively large voltage swings may be applied

to the electrostatic electrode 105. Driver 1121 actively drives signals into the series resonant circuit. EM signals emanate from the coil 134 while ES signals emanate from the electrostatic electrode 105. In order to improved modulation control, a switch 1015 may be connected between node 1123 and ground to selectively short node 1123 to ground in response to a host modulation control signal 1016 and terminate signal radiation from the electrostatic electrode 105 and EM coil 134.

FIG. 11F is a block diagram illustrating a simpler implementation of FIG. 11C. In comparison with FIG. 11C, the transmitter 904I has capacitor 1114 eliminated in comparison with transmitter 904F. Transmitter 904I is a non-resonant transmitter in that the driver 1121 is sufficient enough to drive appropriate voltage levels across coil 1012 without the need of a resonant tank circuit. The transformer ratio or step up (1:N) across the transformer 1001 from coil 1012 to coil 134 is appropriately selected to provide sufficient voltage levels across transformer coil 134 for radiating electrostatic and electromagnetic signals. In this case, modulation block 902 provides a sinusoidal modulation signal on node 913 to the driver 1121. Transmitter 904I includes resistor 1107, having a high resistance value on the order of one mega-ohm, coupled between the node 1106 and ground in order to provide a ground reference and keep the output from the electrostatic electrode 106 from floating. Resistor 1107 may alternatively be connected at a center tap of coil 134 for a balanced voltage across electrodes 105 and 106 In order to improved modulation control, a switch 1015 may be connected between nodes 1105 and 1106 to selectively short them together in response to a host modulation control signal 1016 and terminate signal radiation from the electrostatic electrodes 105 and 106 and EM coil 134.

FIG. 12A and FIG. 12B illustrate a typical frontal view of the electrostatic electrodes for a monopole exciter and a dipole exciter respectively for reader 101B of FIG. 1B and reader 101C of FIG. 1C. In FIG. 12A the electrostatic electrodes 1201 include the exciter electrode 105 and the receiver electrode 108. The exciter electrode 105 is separated from the receiver electrode 108 by a dielectric 1202. In FIG. 12B, the electrostatic electrodes 1211 include the exciter electrodes 105 and 106 and the receiver electrode 108. The exciter electrodes 105 and 106 are separated from the receiver electrode 108 by a dielectric 1212. The electrodes are preferably constructed of a conductor such as copper but may be made of other conductive materials such as gold,

carbon, or aluminum including high impedance materials. In the case where the electrodes are in close proximity to an electromagnetic element for electromagnetic communication, high impedance material is preferred so as to avoid shorting out the electromagnetic field.

Reference is now made to FIG. 13A through FIG. 13C illustrating various circuit block diagrams for both monopole and dipole, electrostatic or electromagnetic readers 101 in accordance with the present invention.

FIG. 13A illustrates a circuit block diagram for a monopole configured electrostatic/electromagnetic reader having a single electrostatic electrode. In accordance therewith, a switched resonant transmitter circuit904I, including a resonant tank comprised of electromagnetic element134 and capacitor 1034, and a switch 1010A is shown coupled between Vcc and ground. The switched resonant transmitter circuit 904I is coupled to the electrostatic electrode 105 for transmission of electrostatic and/or electromagnetic signals. By shielding coil 134 or employing a pot core or toroid device, it will be appreciated by those skilled in the art that the electromagnetic field produced by coil 134 will be greatly suppressed, such that the reader 101 will operate primarily as an electric field reader, only.

Receiver 302J is coupled to the ES electrode 105 and the EM coil 134 at node 1312 for receiving electrostatic signals and/or electromagnetic signals as described above. In this manner, the transmit and receive coil 134 is combined with the transmit and receive ES electrode 105. This design of an ES/EM reader 101 reduces the number of antennas (EM coils and ES electrodes). However, because the transmit energy and signals are fed directly into the receiver 302J a greater amount of filtration is required around the expected data carrier for receiving signals in an RFID system. Receiver 302J includes filter 1310 to provide the necessary filtration and amplifier 324 is provided to amplify the signal after filtering.

It will be appreciated by those skilled in the art that alternate circuit diagrams and topologies are available to generate the required voltage signals ranging from 2 volts to 5000 volts peak-to-peak, as may be required for use by the present invention. By way of example, and not by way of limitation, the switch 1010A may be located between the power source Vcc and the coil 134 in order to derive a sufficiently large voltage for delivery to electrode 105. Alternatively, the switch 1010A may comprise two switches, such as complementary transistors, in order to increase the efficiency of circuit 904I, all without departing from the spirit of the present invention.

FIG. 13B illustrates a circuit block diagram illustrating a second embodiment of a monopole configured electrostatic/electromagnetic reader in accordance with the present invention. Driver 1121 drives signals into the coil 1012 of the transformer 1001. While driver 1121 is depicted as a switch, it will be appreciated by those skilled in the art that several other circuit topologies are available, such as, for example, full and/or half-bridge drivers, differential drivers, balanced and/or unbalanced bridge drivers, class A-D amplifiers, and the like. Coil 134 receives the stepped up signal across the transformer and provides it to the electrostatic electrode 105. Assuming transformer 1001 is a core transformer or is otherwise magnetically shielded such that an emanating magnetic field is suppressed, it will be appreciated by those skilled in the art that the device 101 Fig. 13B will operate substantially as an electric field reader. Receiver 302k can alternatively tap off from node 1324 or node 1325 in order to receive signals and reduce the number of antenna. If receiver taps off from node 1325 the voltage levels may need to be reduced by a circuit such as a resistor divider within the front end of the filter 1320.

FIG. 13C illustrates a dipole active transmitter 904K combined with receiver 302L. Transmitter 904K includes the driver 1101 and the transformer 1001 having EM coil 134 and coil 1012. Capacitor 1014 is provided for resonance and electrostatic electrodes 105 and 106 are respectively coupled to nodes 1333 and 1334. Receiver 302L taps off the transmitter at node 1334 although it could tap off of node 1333 in the alternative. Because the voltage levels are high on nodes 1333 and 1334 it is expected that a voltage reduction circuit, such as a resistor divider, may be part of the front end filtering at filter 1330.

The designs for an ES/EM reader 101 previously described with reference with FIG. 13A through FIG. 13B reduces the number of antennas (EM coils and ES electrodes). However, because the transmit energy and signals are fed directly into the receiver 302J-302L, a greater amount of filtration is required around the expected data carrier for receiving signals in an RFID system having a data carrier of 62.5 kHz and a power carrier of 125 kHz. Accordingly the filters 1310, 1320, and 1330 in receivers 302J-302L provide the added necessary filtration to further reduce the signals around the power carrier. Amplifier 324 is provided to amplify the signal after filtering. However, if the transmit (power carrier) and the receive carrier (data carrier) frequencies are further spread out on the frequency domain from one another, such as in contactless smart card systems, the

filtration requirements become less difficult to achieve for the combined transmit and receive blocks previously described.

Reference is now made to FIG. 14 illustrating in greater detail the components of the electrostatic transceiver 102. As shown in FIG. 14, transceiver 102 may include a circuit 1410 having an analog interface module 1411, a bit-rate generator 1403, a write decoder 1404, an optional charge pump 1405, an input register 1406, a controller 1407, a mode register 1408, a modulator 1409, a memory 1410, and electrostatic electrodes 112 and 113. As previously discussed, electrostatic electrodes 112 and 113 receive electrostatic signals from the electrostatic/electromagnetic reader 101 and modulate or transmit electrostatic signals back to the electrostatic/electromagnetic reader 101. Electrostatic electrodes 112 and 113 are coupled to the analog interface module 1411 over the bi-directional signal lines 1422 and 1423 respectively. The analog interface module 1411 couples to the bit-rate generator 1403 through the clock signal line 1425. Analog interface module 1411 couples to the controller 1407 through the control signal lines 1426 and to the write decoder 1404 through the data in signal line 1424. The modulator 1409 couples to the electrostatic electrode 112 and electrostatic electrode 113 by signal lines 1422 and 1423 respectively. For optimum electrostatic performance, it is desirable to keep the parasitic capacitance measured between signal lines 1422 and 1423 as small as possible.

Controller 1407 controls the functionality of the transceiver 102 in conjunction with the analog interface module 1411. Controller 1407 couples to nearly all components of the electrostatic transceiver 102 except for the electrostatic electrodes 112 and 113. Memory 1410 may be a volatile memory requiring a constant supply of energy or a non-volatile memory such as an EEPROM memory or ferro-electric memory that retains its information when power is no longer supplied. In the case of EEPROM memory, the optional charge pump 1405 may be required in order to boost the voltage of the transceiver power supply in order to write data into the EEPROM memory. Input register 1406 temporarily stores information that is to be written into memory 1410. It may need to store the information due to a delay in the write cycle caused by the charge pump 1405 pumping up or other reasons. In any case, storing data into the input register 1406 allows the controller 1407 to process other information for the transceiver 102. Mode register 1408 reads configuration information for the electrostatic transceiver 102 from memory 1410 and provides this to the controller 1407. Write decoder 1404 analyzes a data

sequence being received by the electrostatic transceiver 102 and determines whether the transceiver can go into a write mode or whether it needs to remain in a receive mode. Modulator 1409 prepares data read from memory 1410 for transmission by the electrostatic transceiver 102. Modulator 1409 can encode and modulate data read from memory 1410 in a number of ways for communication with the reader 101.

When in proximity of a reader 101, the transceiver first detects the excitation signal being emitted by the ES/EM reader 101. The excitation signal is generated by reader 101 at a carrier frequency, commonly referred to as a power carrier frequency or exciter frequency. The power carrier frequency, which may be modulated with data, is preferably 125 kHz. After detecting the excitation signal, the electrostatic transceiver 102 goes through a power management sequence and powers up in order to derive a square wave based on the excitation signal at the carrier frequency which is used as a clock signal for the transceiver. In this manner of generating a clock signal, information received by the electrostatic transceiver 102 is synchronized with the clock signal. This alleviates generating a clock with a clock oscillator and synchronizing the data and clock using phase-locked loop techniques.

The analog interface module 1411 performs multiple functions when receiving and modulating electrostatic signals and charges in an analog signal form. The analog interface module 1411 generally performs the electrostatic communication and power management functions for the electrostatic transceiver 102. Additionally, it performs clock extraction in order to provide a clock to the other components of the electrostatic transceiver 102 including the bit-rate generator 1403 such that the clock is synchronized with received data. The analog interface module 1411 also demodulates the received signal to generate a received data stream. A gap detector (not shown) within the analog interface module 1411 analyzes the data stream and determines if a write operation may be involved. If so, it forwards the data sequence signal to the write decoder 1404. Write decoder 1404 then decodes the data sequence signal to retrieve instruction, data, and address information related to the write operation. If it recognizes the codes as a write command, write decoder 1404 signals to so notify controller 1407. Write decoder 1404 also verifies the validity of the data stream. The decoded instructions and information about the validity of the data stream are provided to controller 1407.

Bit-rate generator 1403 receives as input the clock signal having a carrier frequency (preferably 125 kHz) from a clock extraction circuit (not shown). Bit-rate generator 1403 generates the data transfer rate at which data is transferred from/to memory 1410 during a read or write mode, respectively. Bit-rate generator 1403 generates the data transfer rate by dividing the carrier frequency (preferably 125kHz) by a predetermined factor. The data transfer rate is provided to controller 1407. In the preferred embodiment, bit-rate generator 1403 divides by either sixteen or thirty-two such that the data transfer rate can be programmed to be either 125 kHz/16 (7812.5 bits/second) or 125 kHz/32 (3906.25 bits/second).

FIG. 15 illustrates a block diagram of the electromagnetic transceiver 104. As shown in FIG. 15, transceiver 104 includes circuit 1510 having an analog interface module 1511, a bit-rate generator 1403, a write decoder 1404, a charge pump 1405, an input register 1406, a controller 1407, a mode register 1408, a modulator 1509, a memory 1410, and the electromagnetic element114 and the resonant capacitor 115. Electromagnetic element114 receives electromagnetic signals from the electrostatic/electromagnetic reader 101 and sends electromagnetic signals back to the electrostatic/electromagnetic reader 101. The functionality of the electromagnetic transceiver 104 is similar to the functionality of the electrostatic transceiver 102 that was previously described. The main difference between the electromagnetic transceiver 104 and electrostatic transceiver 102 is in the respective analog interface modules 1511 and 1411. While the basic function of the analog interface modules 1511 and 1411 are similar, the initial processing of the received signals and the final processing of modulated signals are different. That is, the electrodes and coils with supporting components will differ. The other components of the electromagnetic transceiver 104 consisting of the bit-rate generator 1403, the write decoder 1404, the optional charge pump 1405, the input register 1406, the controller 1407, the mode register 1408, and the memory 1410 have the same reference designators as in the electrostatic transceiver 102 and function similarly as described above.

The analog interface module 1511 performs multiple functions when receiving and modulating electromagnetic signals in an analog signal form. The analog interface module 1511 performs the charge receiving and power supply management function for the electromagnetic transceiver 104. Additionally, it performs clock extraction in order to provide a clock to the other components of the electromagnetic transceiver 104 including

the bit-rate generator 1403 such that the clock is synchronized with received data. The analog interface module 1511 also demodulates the received signal to generate a received data stream. A gap detector (not shown) within the analog interface module 1511 analyzes the data stream and determines if a write operation may be involved. If so, it forwards the data sequence signal to the write decoder 1404. Write decoder 1404 then decodes the data sequence signal to retrieve instruction, data, and address information related to the write operation. If it recognizes the codes as a write command, write decoder 1404 signals to so notify controller 1407. Write decoder 1404 also verifies the validity of the data stream. The decoded instructions and information about the validity of the data stream are provided to controller 1407.

The modulator 1509 has similar functionality to the modulator 1409, but may have the final drive or load modulation circuitry tailored to drive or modulate signals onto the electromagnetic element114.

FIG. 16 illustrates a block diagram of the electrostatic/electromagnetic transceiver 109. As shown in FIG. 16, transceiver 109 includes circuit 1610 having an analog interface module 1611, a bit-rate generator 1403, a write decoder 1404, an optional charge pump 1405, an input register 1406, a controller 1407, a mode register 1408, a modulator 1609, a memory 1410, an electromagnetic element 124, a resonant capacitor 125 and electrostatic electrodes 122 and 123. Electromagnetic element124 receives electromagnetic signals from the electrostatic/electromagnetic reader 101 and modulates electromagnetic signals back to the electrostatic/electromagnetic reader 101. Electrostatic electrodes 122 and 123 receive electrostatic signals from the electrostatic/electromagnetic reader 101 and modulate electrostatic signals back to the electrostatic/electromagnetic reader 101. The capacitor 125 is provided to create a resonant circuit for receiving electromagnetic signals.

The functionality of the electrostatic/electromagnetic transceiver 109 is similar to the functionality of the electrostatic transceiver 102 that was previously described. The main difference between the electromagnetic transceiver 104 and ES/EM transceiver 109 is in the respective analog interface modules 1611 and 1411. While the basic function of the analog interface modules 1611 and 1411 are similar, the initial processing of received signals and the final processing of modulated signals may be slightly different. The other components of the ES/EM transceiver 109 consisting of the bit-rate generator 1403, the

write decoder 1404, the charge pump 1405, the input register 1406, the optional controller 1407, the mode register 1408, and the memory 1410, have the same reference designators as in the electrostatic transceiver 102 and function similarly as described above.

The analog interface module 1611 performs multiple functions when receiving and modulating electromagnetic or electrostatic signals in an analog signal form. Analog interface module 1611 may be used for combined electromagnetic/electrostatic communication, electromagnetic communication only, and electrostatic communication only. The analog interface module 1611 performs the charge receiving and power supply management function for the ES/EM transceiver 109. Additionally, it performs clock extraction in order to provide a clock to the other components of the ES/EM transceiver 109 including the bit-rate generator 1403 such that the clock is synchronized with received data. A gap detector (not shown) within the analog interface module 1611 analyzes the data stream and determines if a write operation may be involved. If so, it forwards the data sequence signal to the write decoder 1404. Write decoder 1404 then decodes the data sequence signal to retrieve instruction, data, and address information related to the write operation. If it recognizes the codes as a write command, write decoder 1404 signals to so notify controller 1407. Write decoder 1404 also verifies the validity of the data stream. The decoded instructions and information about the validity of the data stream are provided to controller 1407.

The modulator 1609 has similar functionality to the modulator 1409 but may have the final drive or load modulation circuitry tailored to drive or modulate signals onto the electromagnetic element124 and electrostatic electrodes 122 and 123.

While the preferred embodiments of the electrostatic/electromagnetic reader 101 have been described with reference to RFID technology, the embodiments may be applied to other near field technology including smart card technology where the power carrier frequency and the data carrier frequency are further separated. Additionally, it can be appreciated that other electromagnetic RFID transceivers or electrostatic transceivers may be encompassed by the present invention.

The present invention has many advantages over the prior art. The present invention allows a user to introduce electrostatic technology into an electromagnetic technology based communication system such that there is backward compatibility. Additionally, the present invention provides that one need not suffer the total loss in

investment in prior electromagnetic based communication technology, the readers need only be replaced. The present invention provides for low cost RFID transceivers such that disposable applications are possible such as with visitor badges in an access controlled facility. The present invention provides that minimal system support need be changed in order to introduce new electrostatic technology.

While the invention has been described in conjunction with specific embodiments thereof, additional advantages and modifications will readily occur to those skilled in the art. The invention, in its broader aspects, is therefore not limited to the specific details, representative apparatus, and illustrative examples shown and described. Various alterations, modifications and variations will be apparent to those skilled in the art in light of the foregoing description. Thus, it should be understood that the invention is not limited by the foregoing description, but embraces all such alterations, modifications and variations in accordance with the spirit and scope of the appended claims.

CLAIMS

What is claimed is:

1. A combined electrostatic and electromagnetic reader, comprising:

a transmitter, coupled to an electrostatic electrode and an electromagnetic element, for transmitting an excitation signal via the electrostatic electrode and the electromagnetic element;

a receiver, coupled to the electrostatic electrode and the electromagnetic element, for receiving electrostatic signals and electromagnetic signals from at least one of an electromagnetic device and an electrostatic device;

a circuit, coupled to at least one of the transmitter and the receiver, for processing at least one of the electrostatic signals and the electromagnetic signals.

2. The reader of claim 1, wherein the receiver couples to the electrostatic electrode to receive electrostatic signals when the electrostatic device is communicating and otherwise couples to the electromagnetic element to receive electromagnetic signals when the electromagnetic device is communicating.

3. The reader of claim 1 wherein the receiver is switchably coupled to one of the electrostatic electrode and the electromagnetic element.

4. A reader, comprising:

an electrostatic electrode;

a transmitter, coupled to the electrostatic electrode, for transmitting an excitation signal via the electrostatic electrode;

a receiver, coupled to the electrostatic electrode, for receiving electrostatic signals from an electrostatic device; and

a circuit, coupled to at least one of the transmitter and the receiver, for processing the electrostatic signals.

5. A combined electrostatic and electromagnetic receiver for receiving electrostatic and electromagnetic signals, the receiver comprising:

an electrostatic electrode for receiving the electrostatic signals;

a prefilter, coupled to the electrostatic electrode for receiving electrostatic signals, having at least one electromagnetic element for receiving the electromagnetic signals, for filtering the electromagnetic signals and the electrostatic signals and attenuating electromagnetic signals and the electrostatic signals in an undesired range of frequencies; and

an amplifer, coupled to the prefilter, for amplifying the electrostatic signals and the electromagnetic signals.

6. A combined electrostatic and electromagnetic reader, comprising:

an exciter coupled to a first electrostatic electrode and a first electromagnetic coil, generating an excitation signal and modulating the excitation signal to transmit signals electrostatically through the first electrostatic electrode and electromagnetically through the first electromagnetic coil;

a receiver coupled to a second electrostatic electrode, a second electromagnetic elementand a processor, receiving electrostatic signals transmitted by an electrostatic transceiver from the second electrostatic electrode and receiving electromagnetic signals transmitted by an electromagnetic transceiver from the second electromagnetic induction coil and causing the processor to process the electrostatic signals and the electromagnetic signals;

the first electrostatic electrode coupled to the exciter, for electrostatically transmitting the electrostatic signals to the electrostatic transceiver;

the first electromagnetic element coupled to the first electrostatic electrode and the exciter, for electromagnetically transmitting electromagnetic signals to the electromagnetic transceiver;

the second electrostatic electrode coupled to the receiver, for electrostatically receiving electrostatic signals transmitted by the electrostatic transceiver;

the second electromagnetic element coupled to the second electrostatic electrode and the receiver, for electromagnetically receiving electromagnetic signals transmitted by the electromagnetic transceiver; and

the processor coupled to the exciter and having an interface for coupling to a computer, for transmitting information to and receiving information from the computer and for transmitting information to the exciter.

7. The combined electrostatic and electromagnetic reader of claim 22, wherein the receiver comprises:

a bandpass filter coupled to the second electrostatic electrode and the second electromagnetic coil, having a pass frequency to avoid filtering the electrostatic signals and the electromagnetic signals over a range of frequency around the pass frequency which are received; and

an amplifier coupled to the bandpass filter, having a gain for amplifying a signal received from the bandpass filter.

8. A method for electrostatic communication between an electrostatic/electromagnetic reader and an electrostatic transceiver and electromagnetic communication between an the electrostatic/electromagnetic reader and an electromagnetic transceiver, comprising the steps of:

(a) generating an excitation signal;

(b) transmitting a first electrostatic signal and a first electromagnetic signal responsive to the excitation signal;

(c) receiving the electrostatic signal to energize the electrostatic transceiver and process the received electrostatic signal; and

(d) receiving the electromagnetic signal to energize the electromagnetic transceiver and process the received electromagnetic signal.

9. The method of claim 8, further comprising the steps of:

(e) communicating a second electrostatic signal to the electrostatic/electromagnetic reader; and

(f) receiving the second electrostatic signal for processing by the electrostatic/electromagnetic reader.

10. The method of claim 9 wherein the electrostatic/electromagnetic reader comprises:

a bandpass filter having a pass frequency to avoid filtering the electrostatic signals and the electromagnetic signals over a range of frequency around the pass frequency which are received; and

an amplifier coupled to the bandpass filter, having a gain for amplifying a signal received from the bandpass filter.

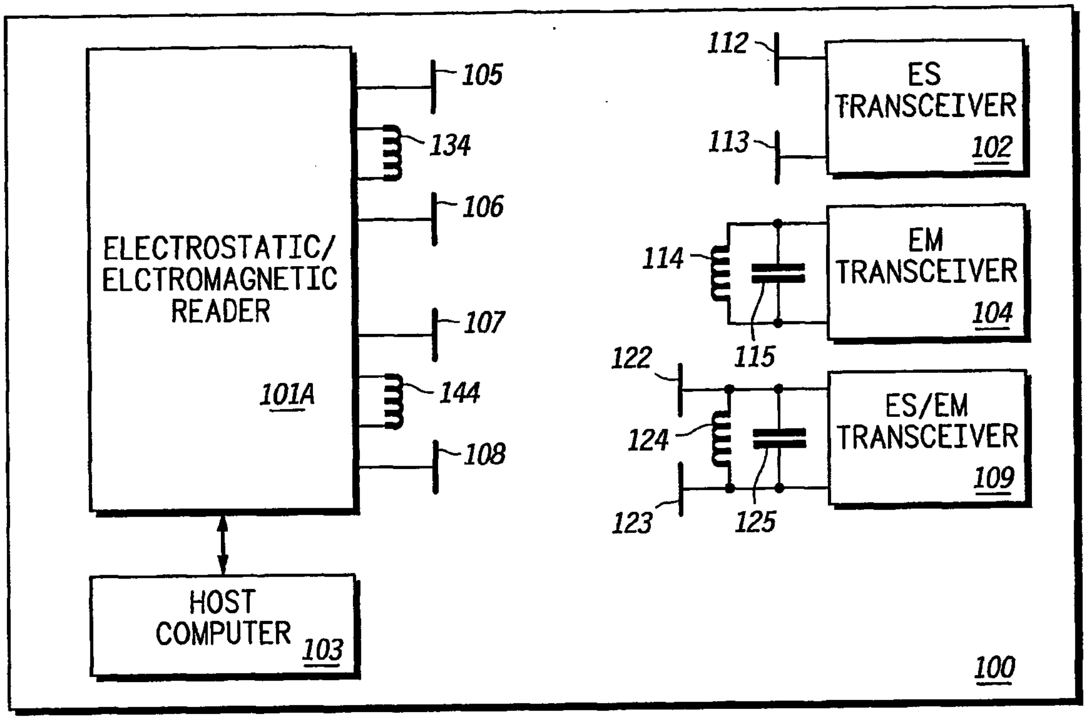

ELECTROSTATIC/
ELCTROMAGNETIC
READER
101A
105
134
106
107
144
108
HOST
COMPUTER
103
112
113
ES
TRANSCEIVER
102
114
115
EM
TRANSCEIVER
104
122
124
123
125
ES/EM
TRANSCEIVER
109
100

FIG.1A

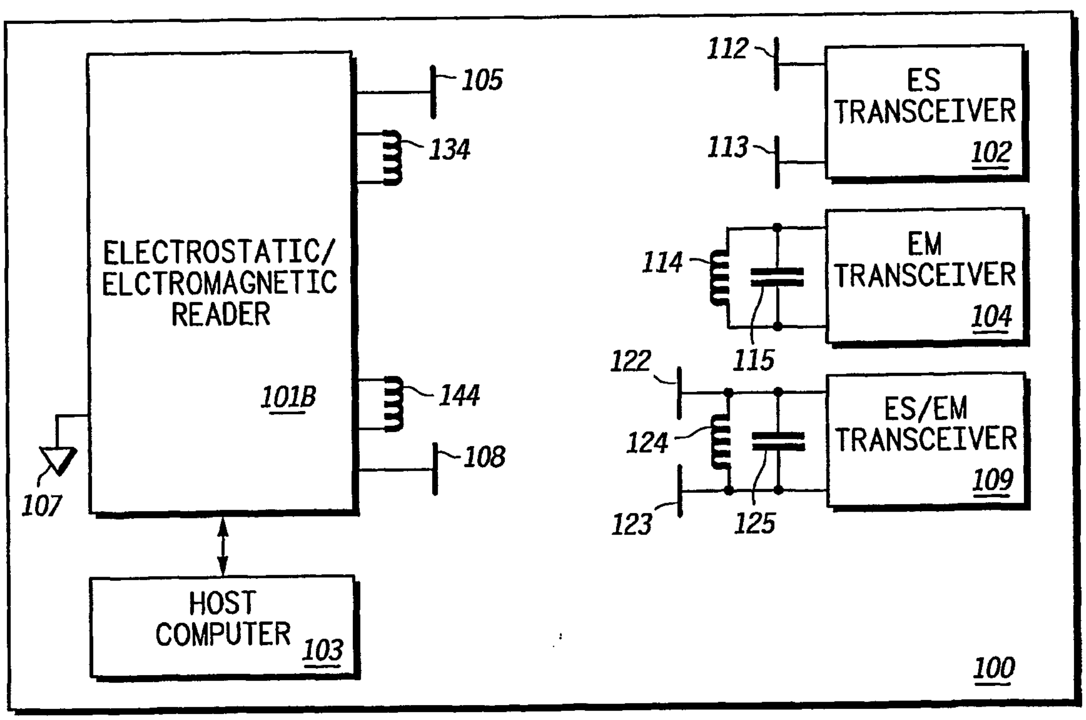

ELECTROSTATIC/
ELCTROMAGNETIC
READER
101B
105
134
144
108
107
HOST
COMPUTER
103
112
113
ES
TRANSCEIVER
102
114
115
EM
TRANSCEIVER
104
122
124
123
125
ES/EM
TRANSCEIVER
109
100

FIG.1B

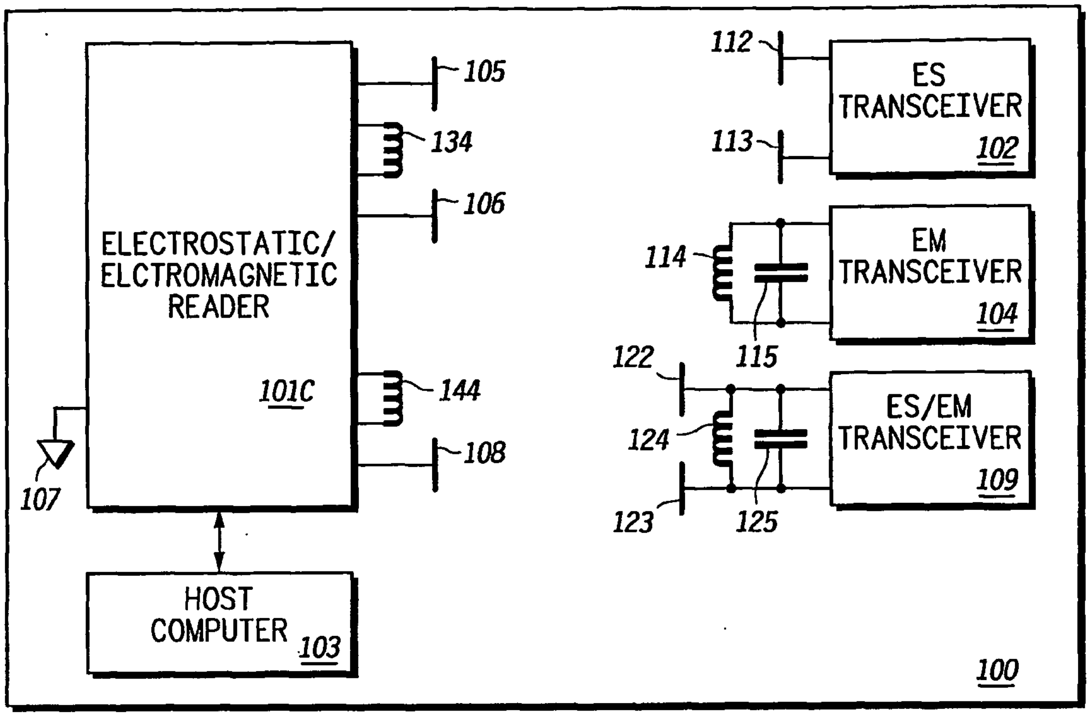

ELECTROSTATIC/
ELCTROMAGNETIC
READER
101C
105
134
106
144
108
107
HOST
COMPUTER
103
112
113
ES
TRANSCEIVER
102
114
115
EM
TRANSCEIVER
104
122
124
123
125
ES/EM
TRANSCEIVER
109
100

FIG.1C

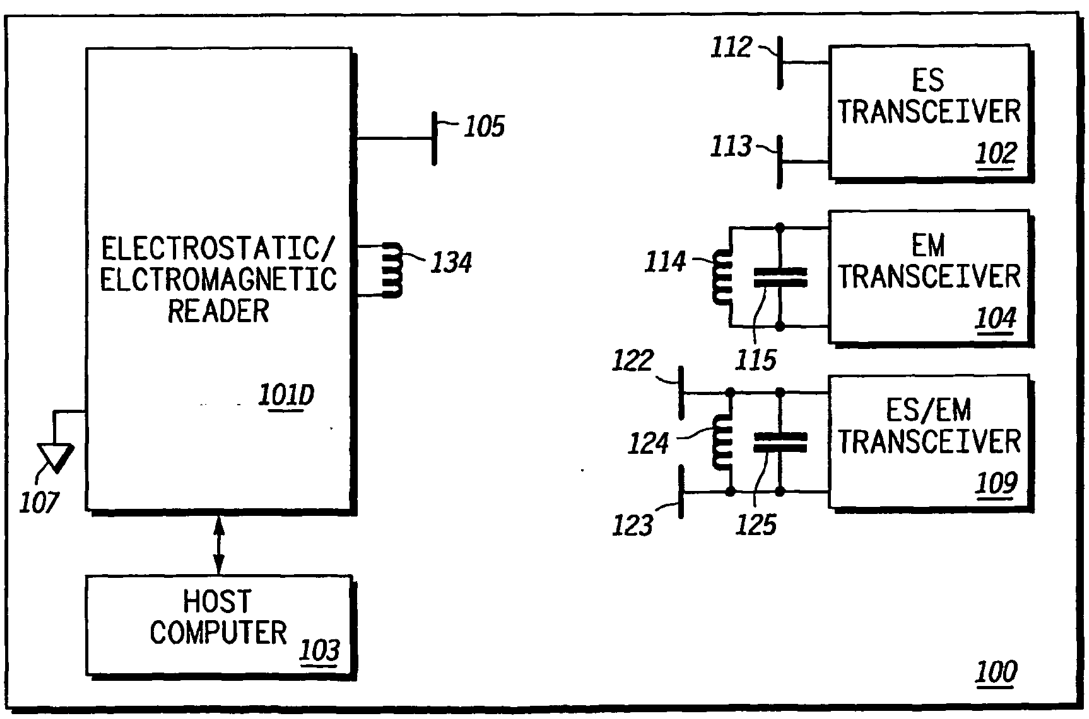
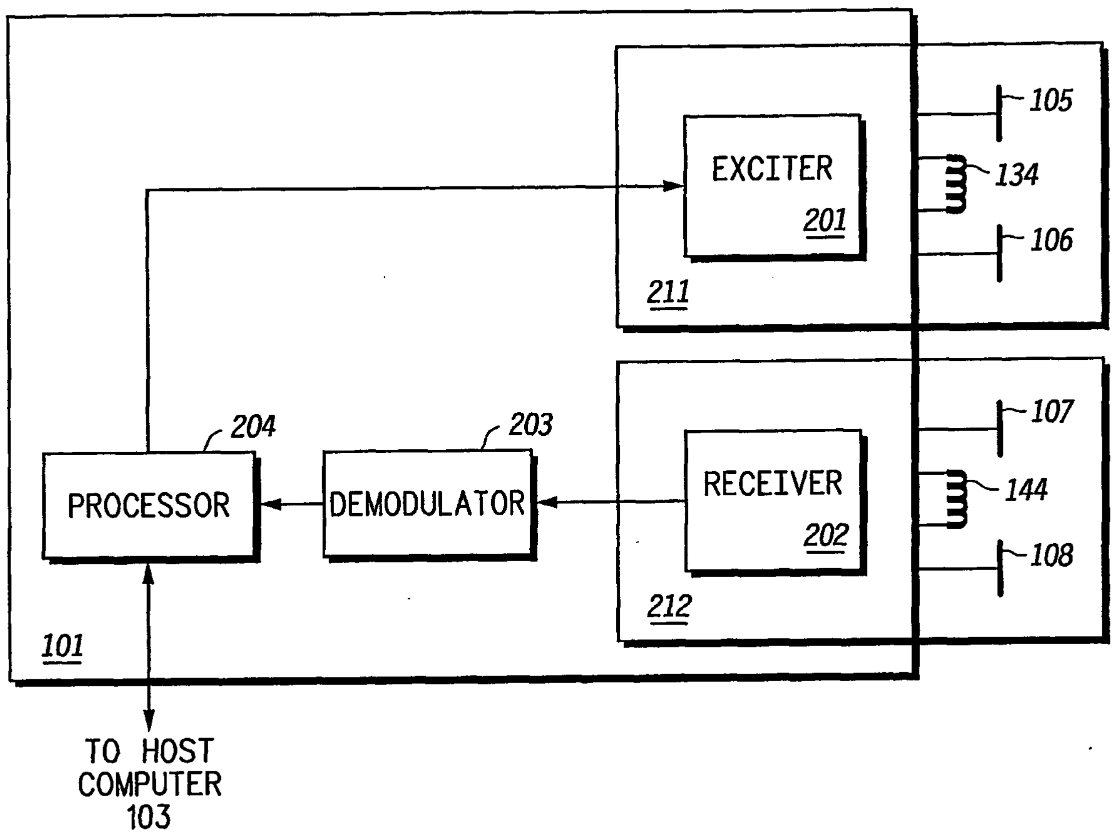

ELECTROSTATIC/
ELCTROMAGNETIC
READER
101D
105
134
107
HOST
COMPUTER
103
112
113
ES
TRANSCEIVER
102
114
115
EM
TRANSCEIVER
104
122
124
123
125
ES/EM
TRANSCEIVER
109
100

FIG.1D



EXCITER
201
211
105
134
106
107
144
108
RECEIVER
202
212
204
PROCESSOR
203
DEMODULATOR
101
TO HOST
COMPUTER
103

FIG.2

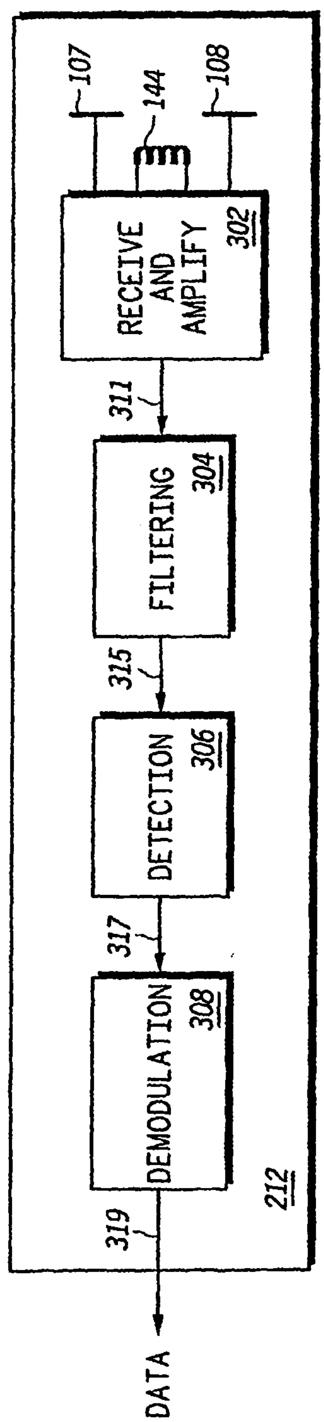

107
144
108
RECEIVE AND AMPLIFY
302
311
FILTERING
304
315
DETECTION
306
317
DEMODULATION
308
212
319
DATA

FIG.3

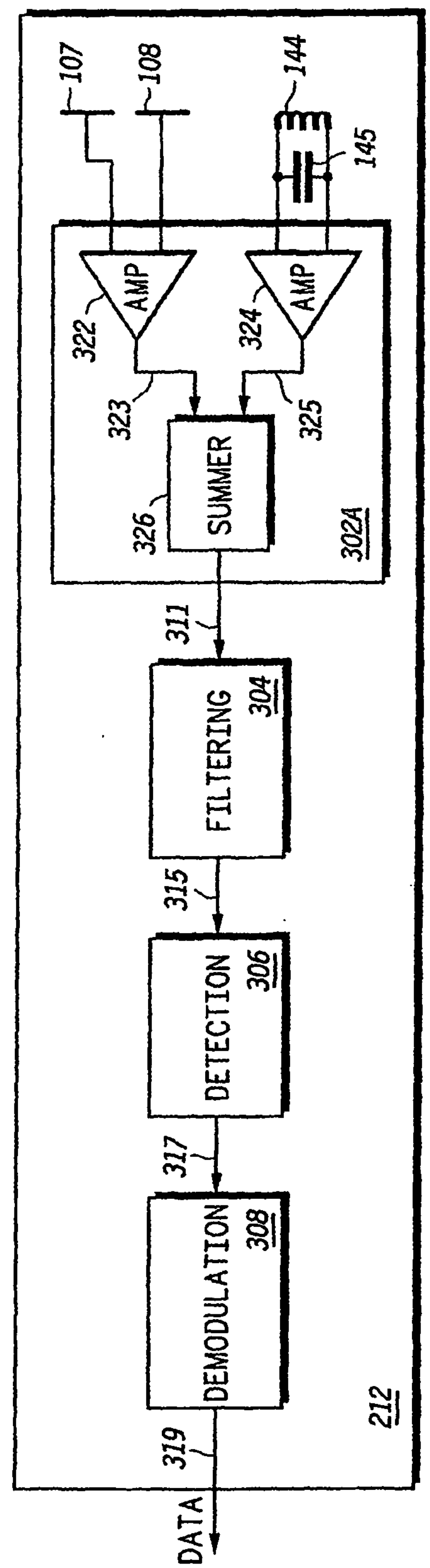

107
108
144
145
AMP
322
AMP
324
323
325
SUMMER
326
302A
311
FILTERING
304
315
DETECTION
306
317
DEMODULATION
308
212
319
DATA

FIG.4A

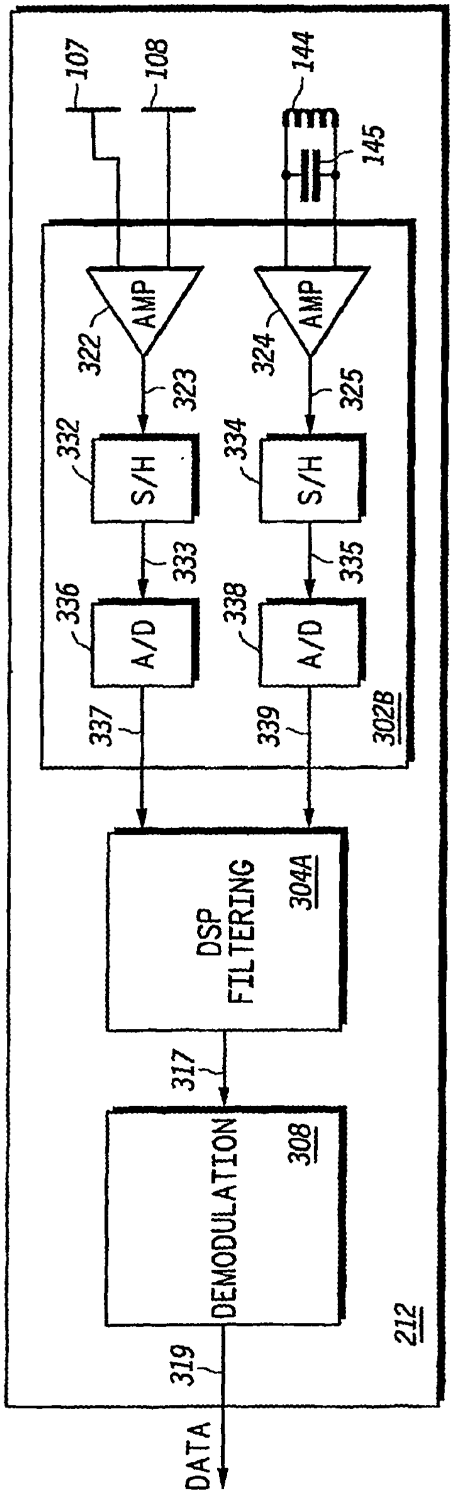

107
108
144
145
AMP
AMP
322
323
324
325
S/H
332
333
S/H
334
335
A/D
336
337
A/D
338
339
302B
DSP FILTERING
304A
317
DEMODULATION
308
319
212
DATA

FIG. 4B

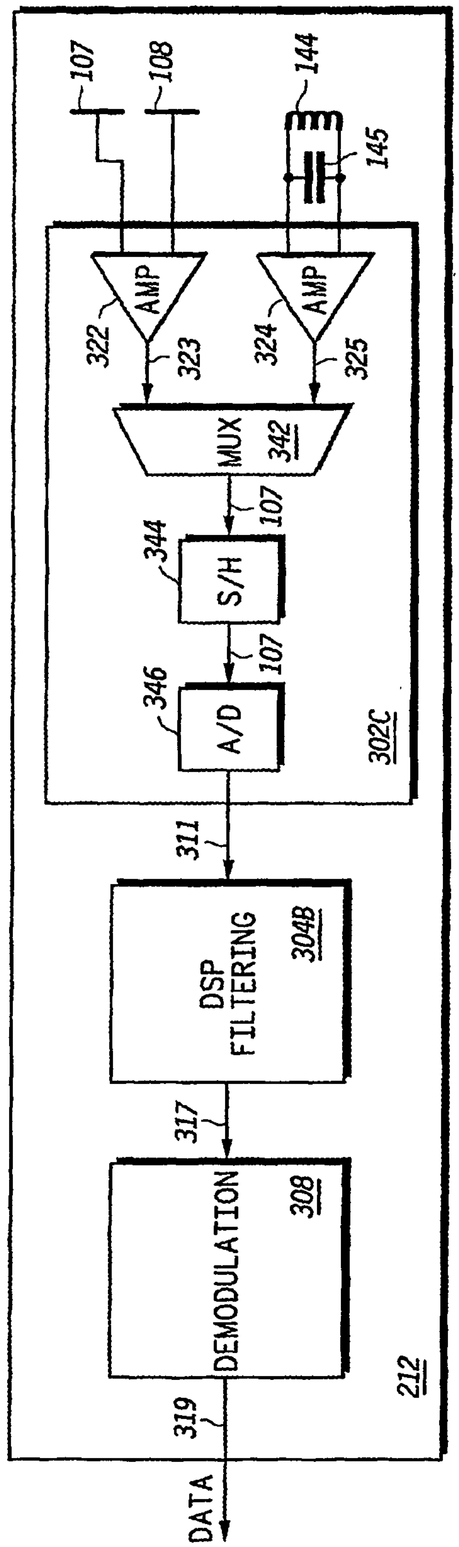

107
108
144
145
AMP
AMP
322
323
324
325
MUX
342
107
S/H
344
107
A/D
346
302C
311
DSP FILTERING
304B
317
DEMODULATION
308
319
212
DATA

FIG. 4C

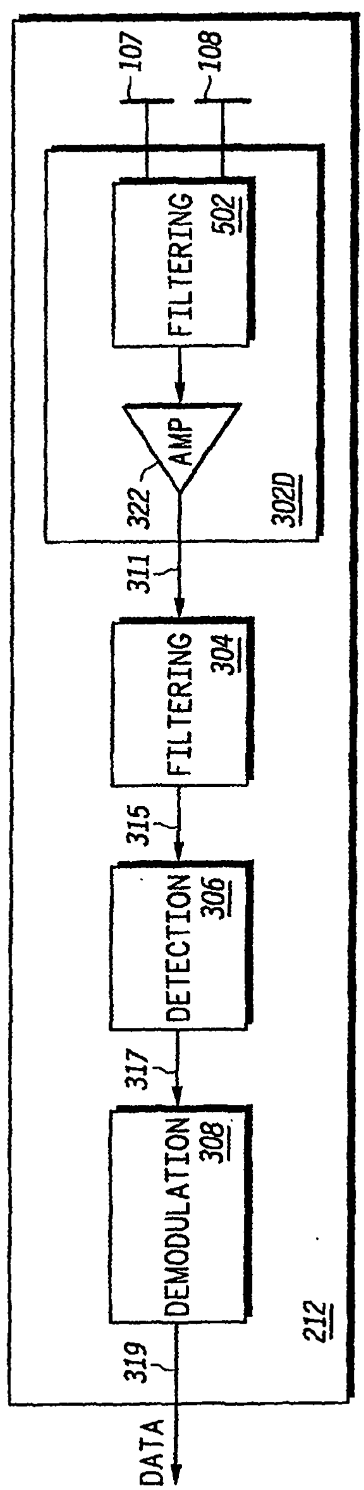

107
108
FILTERING
502
AMP
322
302D
311
FILTERING
304
315
DETECTION
306
317
DEMODULATION
308
212
319
DATA

FIG.5

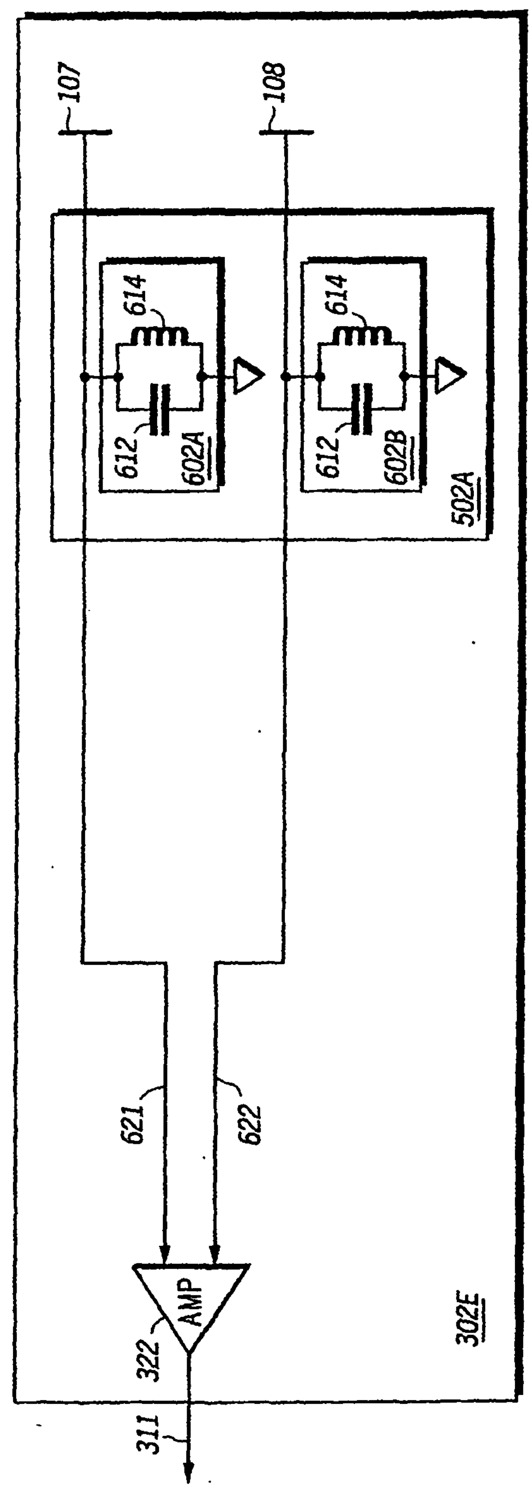

107
108
614
612
602A
614
612
602B
502A
621
622
AMP
322
302E
311

FIG.6A

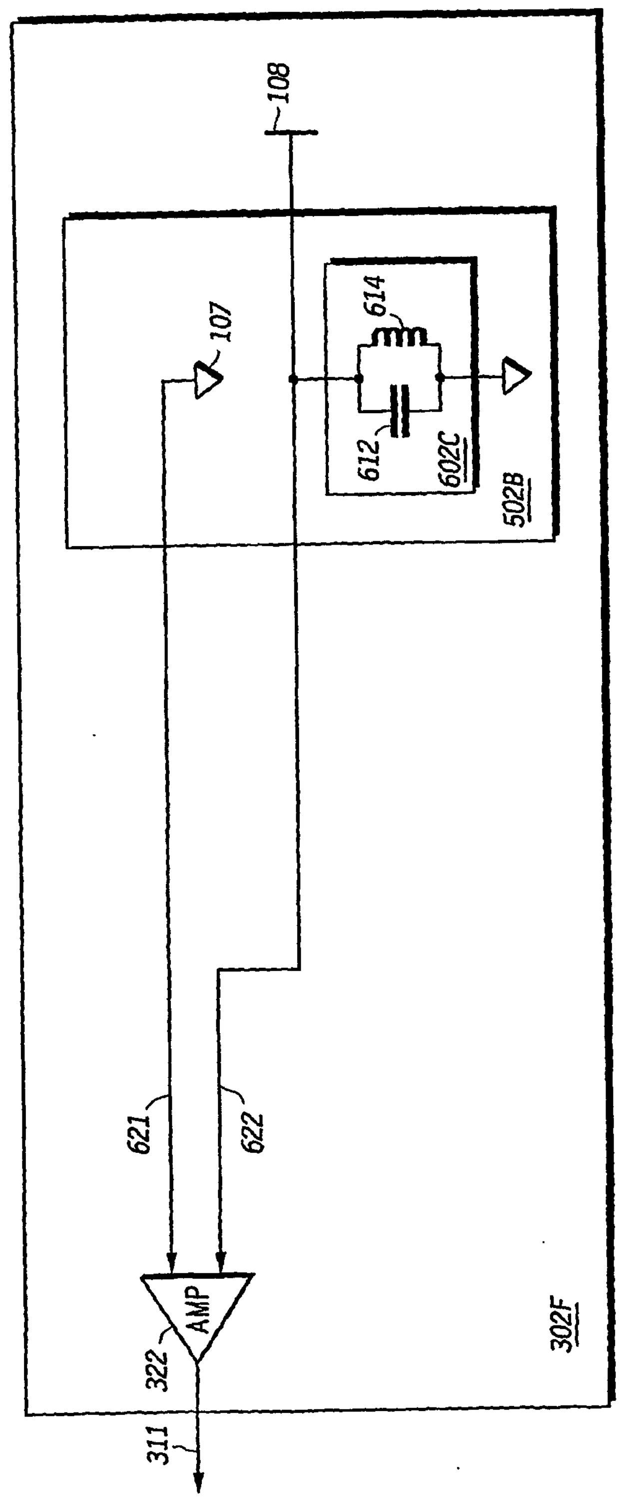


FIG.6B

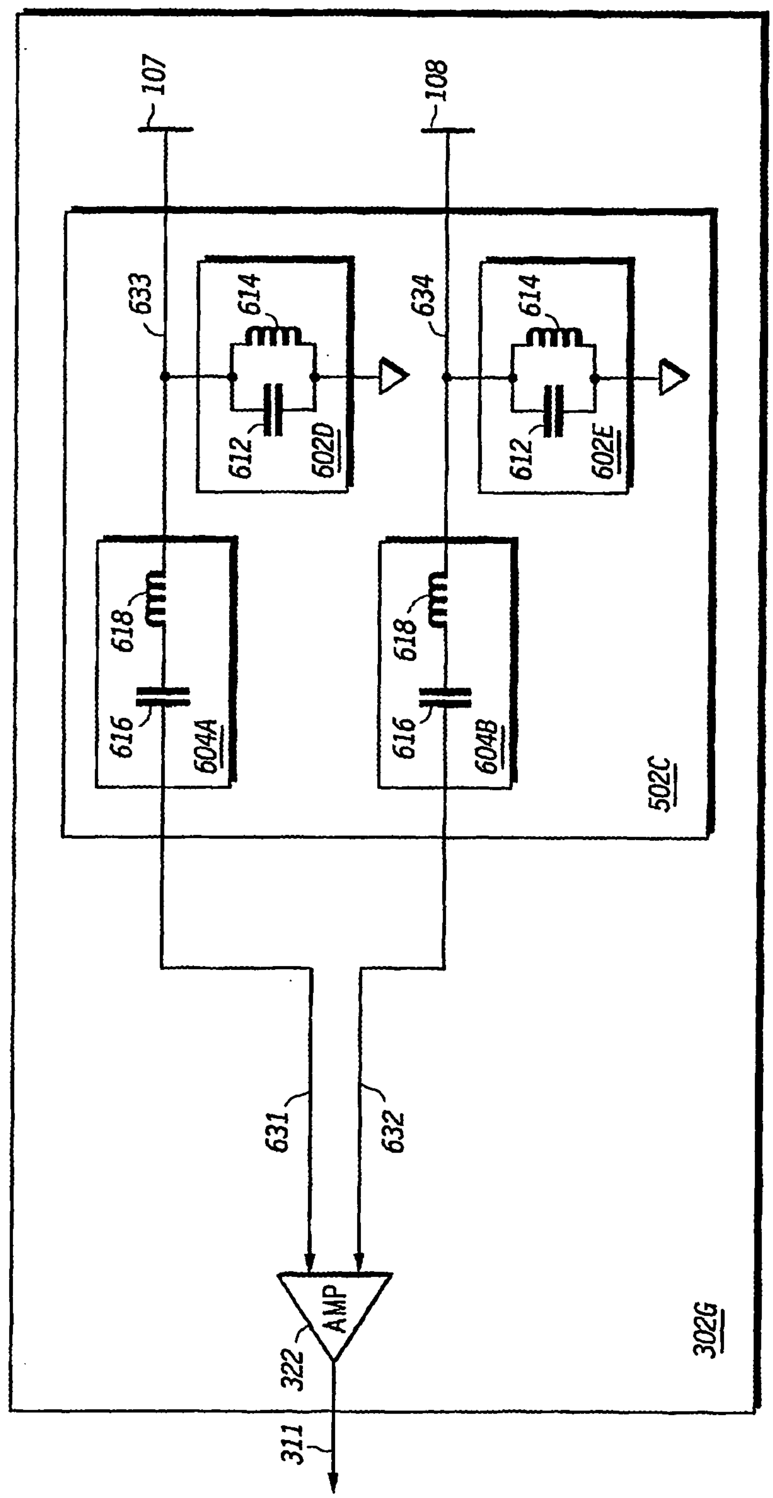

107
108
633
634
614
614
612
612
602D
602E
618
618
616
616
604A
604B
502C
631
632
AMP
322
311
302G

FIG. 6C

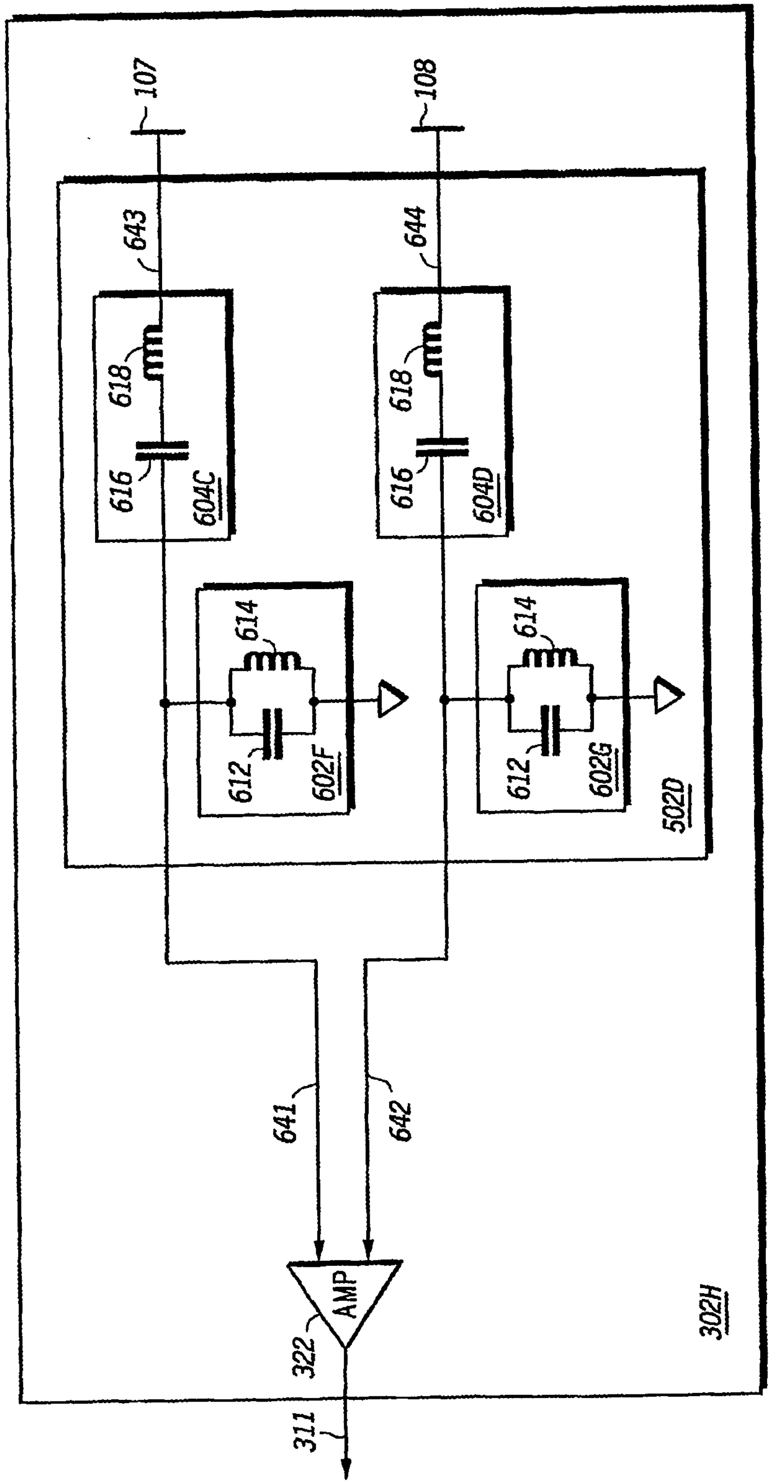

107
108
643
644
618
618
616
616
604C
604D
614
614
612
612
602F
602G
502D
641
642
AMP
322
302H
311

FIG.6D

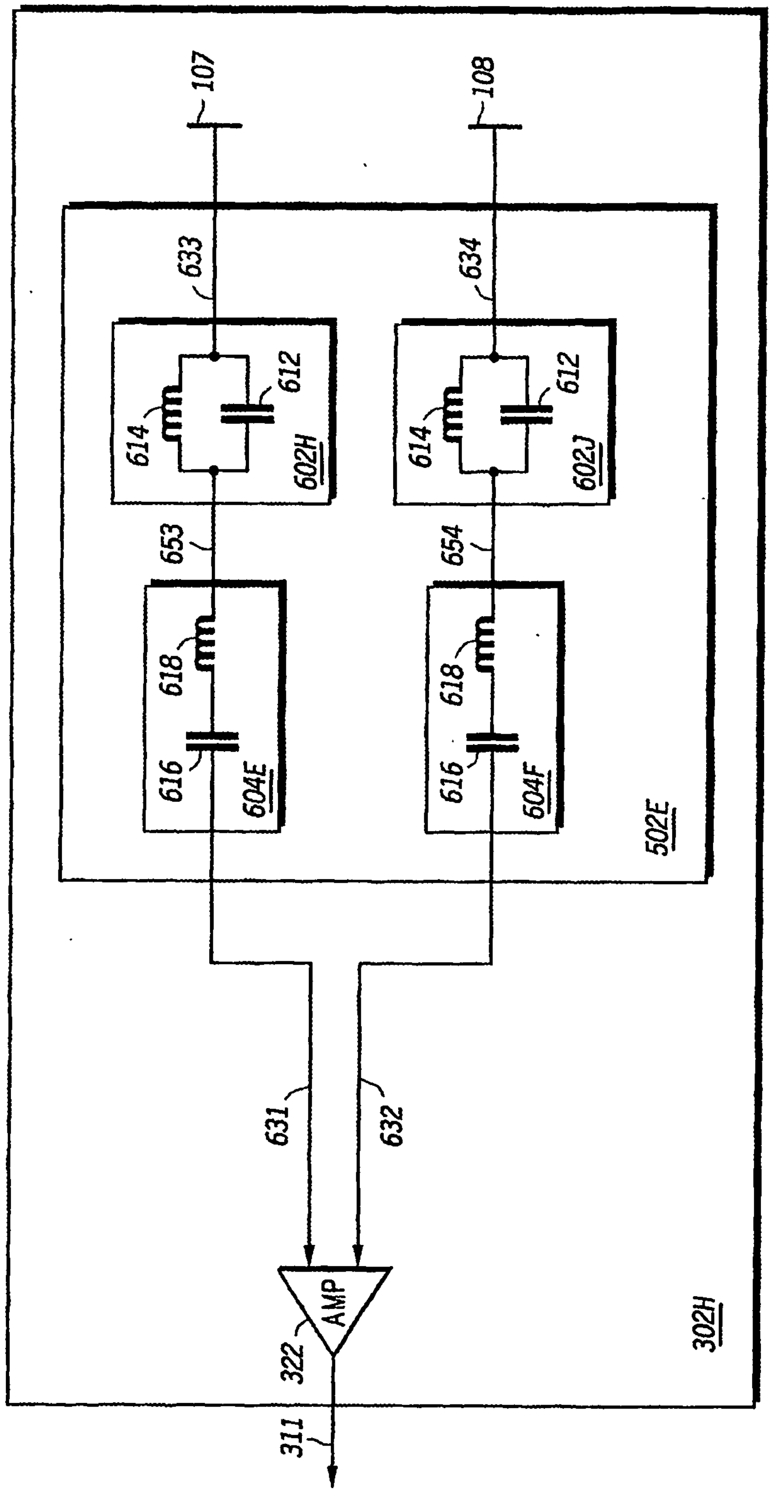

107
108
633
634
614
612
602H
614
612
602J
653
654
618
616
604E
618
616
604F
502E
631
632
AMP
322
302H
311

FIG. 6E

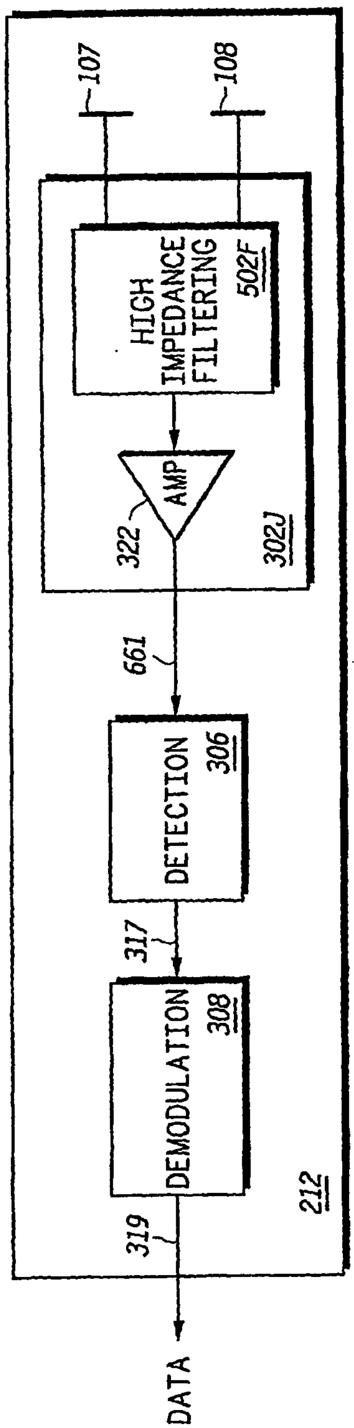

107
108
HIGH IMPEDANCE FILTERING
502F
AMP
322
302J
661
DETECTION
306
317
DEMODULATION
308
212
319
DATA

FIG.6F

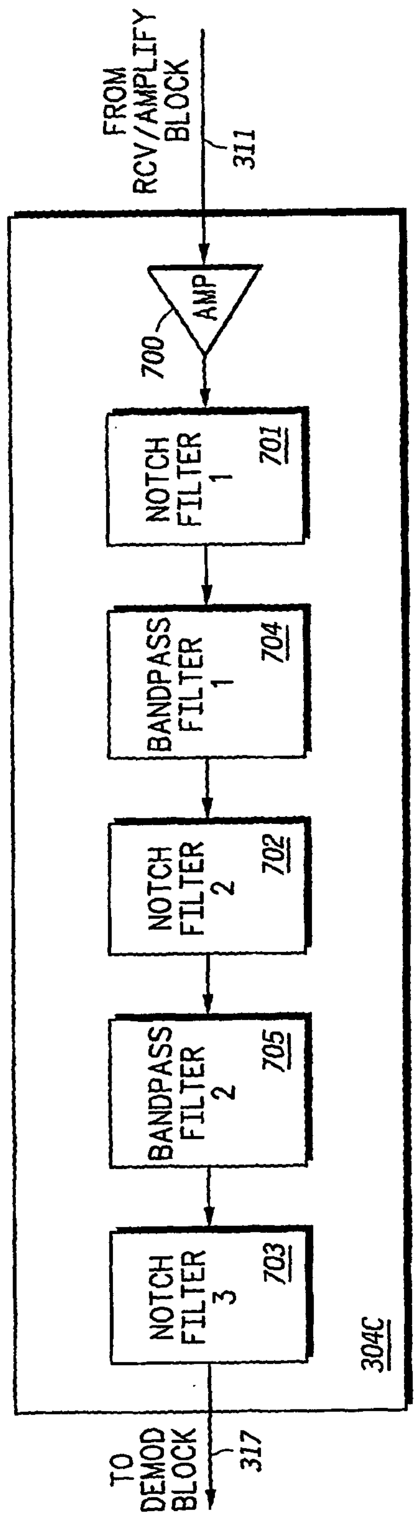

FROM RCV/AMPLIFY BLOCK
311
AMP
700
NOTCH FILTER 1
701
BANDPASS FILTER 1
704
NOTCH FILTER 2
702
BANDPASS FILTER 2
705
NOTCH FILTER 3
703
304C
TO DEMOD BLOCK
317

FIG.7

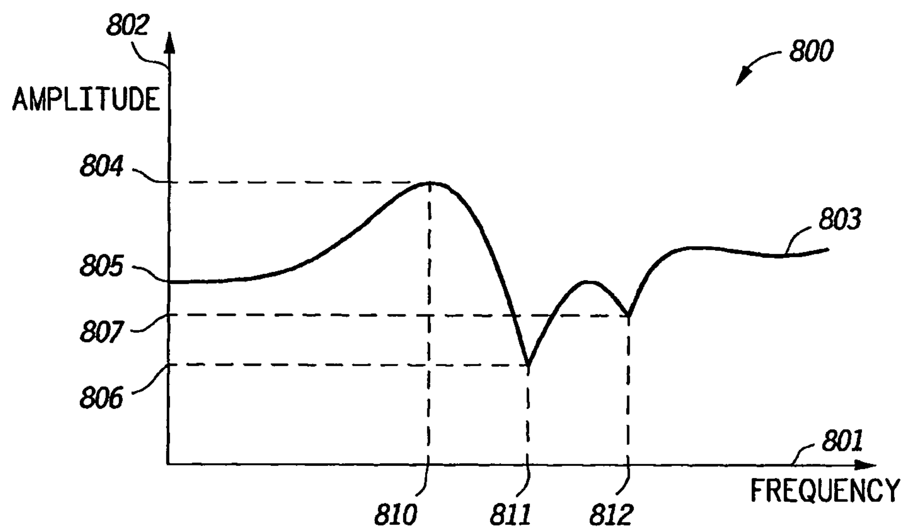

802
AMPLITUDE
800
804
803
805
807
806
801
FREQUENCY
810
811
812

FIG.8

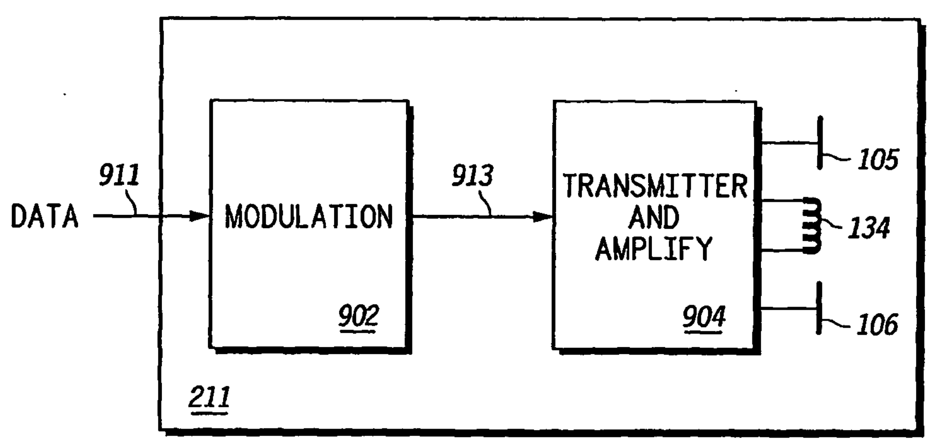

911
DATA
MODULATION
902
913
TRANSMITTER AND AMPLIFY
904
105
134
106
211

FIG.9

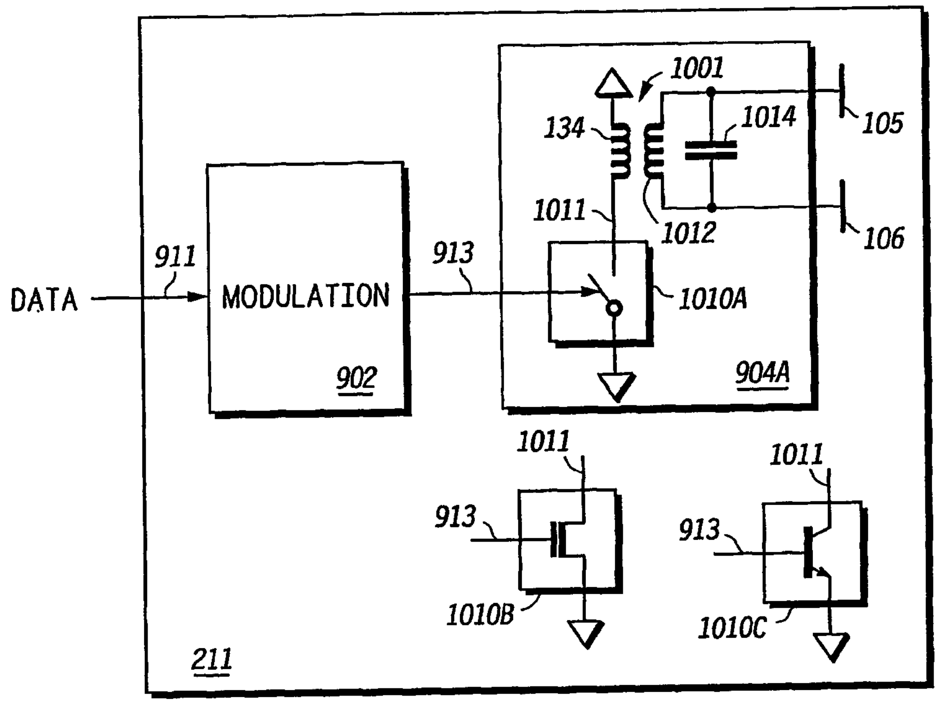


FIG.10A

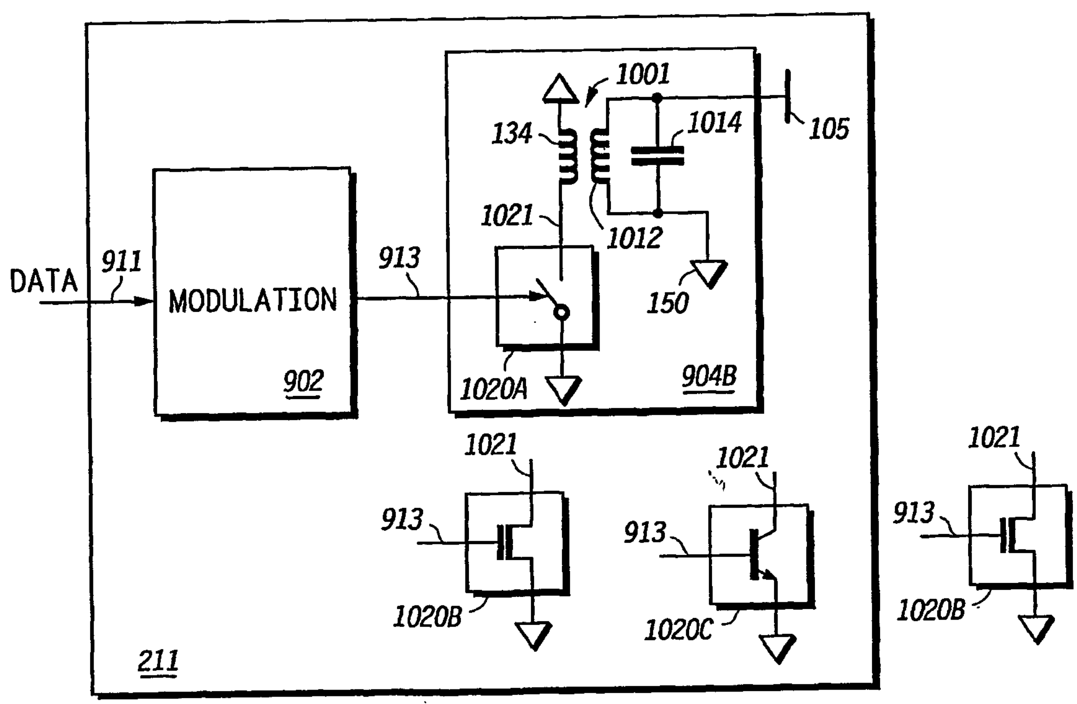


FIG.10B

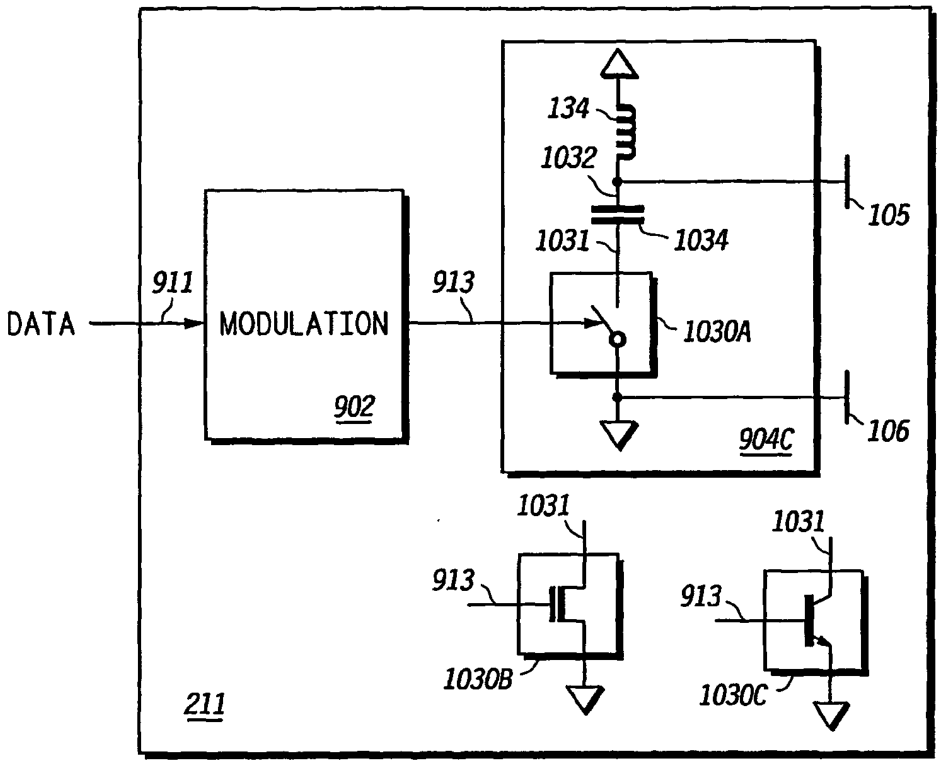


FIG.10C

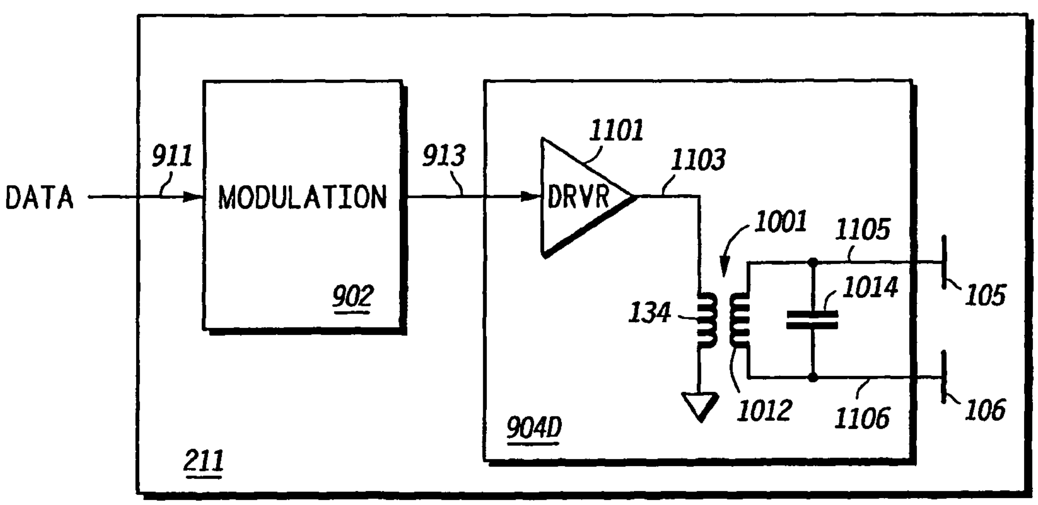


FIG.11A

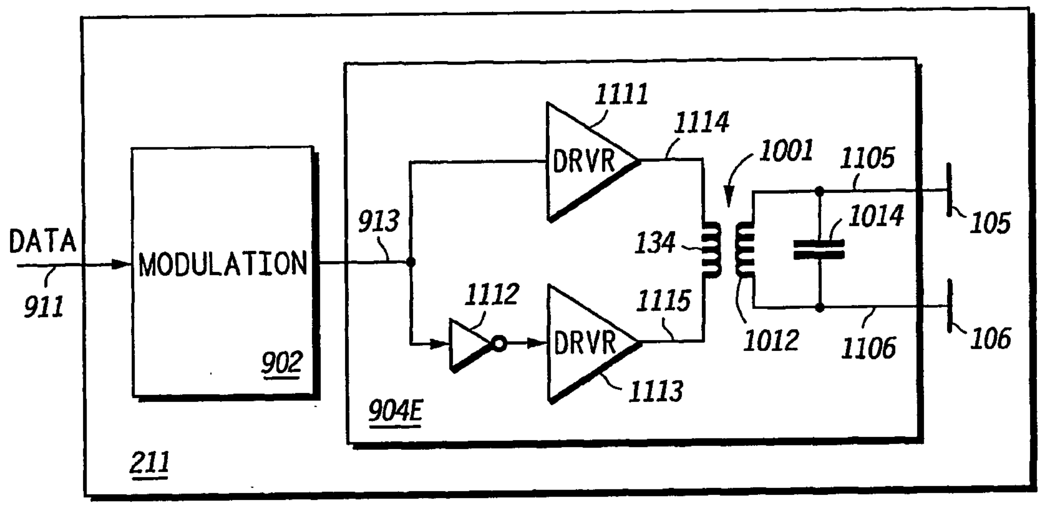


FIG.11B

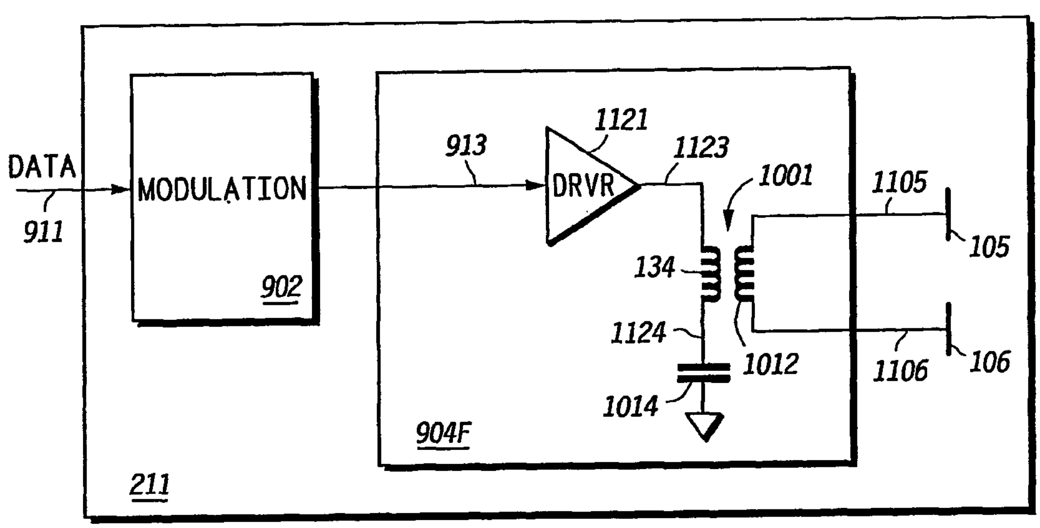


FIG.11C

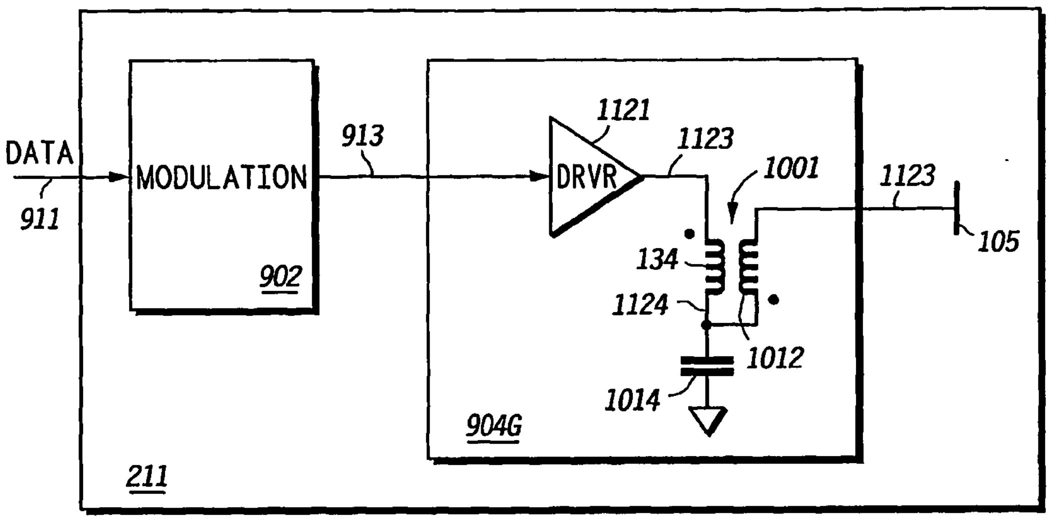


FIG.11D

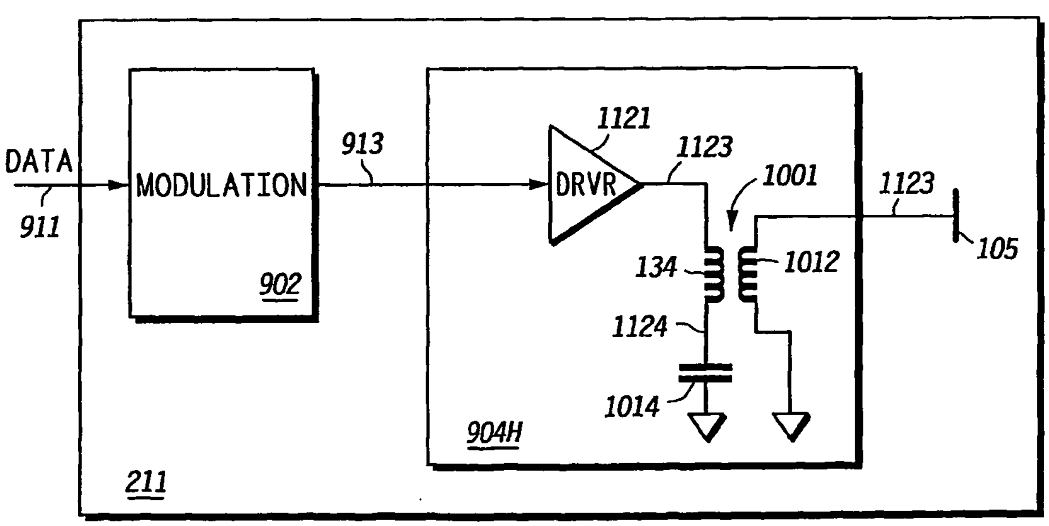


FIG.11E

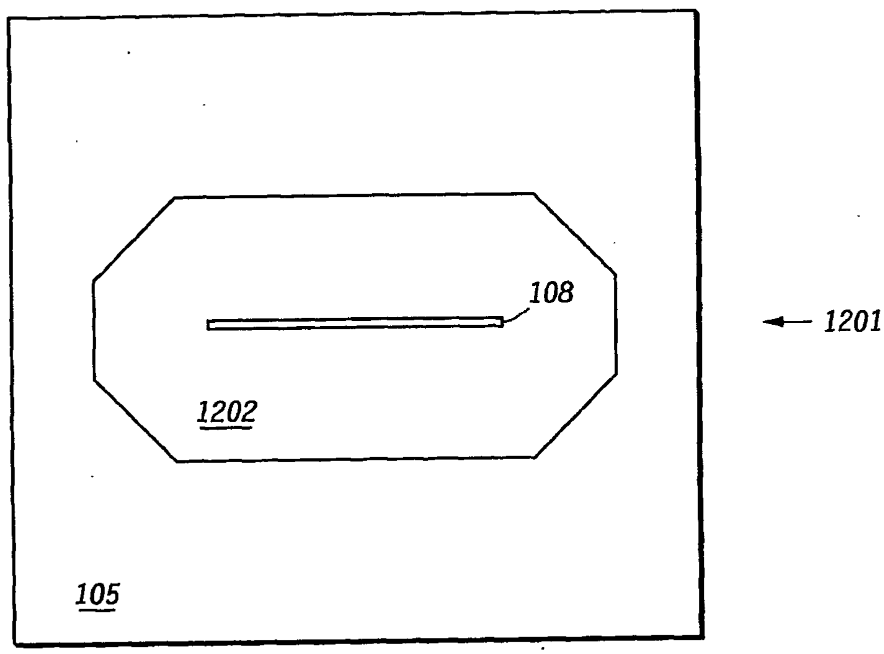


FIG.12A

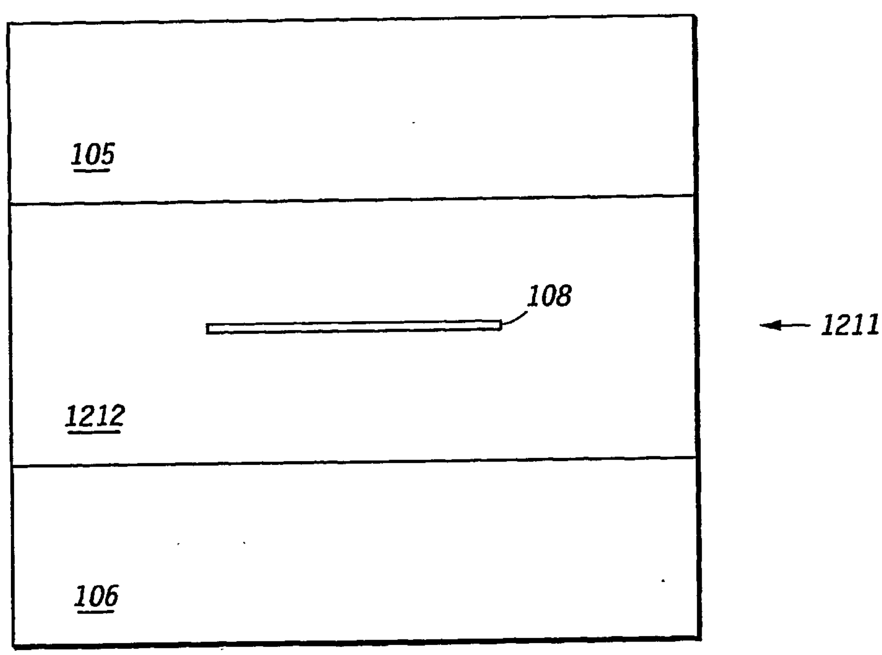


FIG.12B

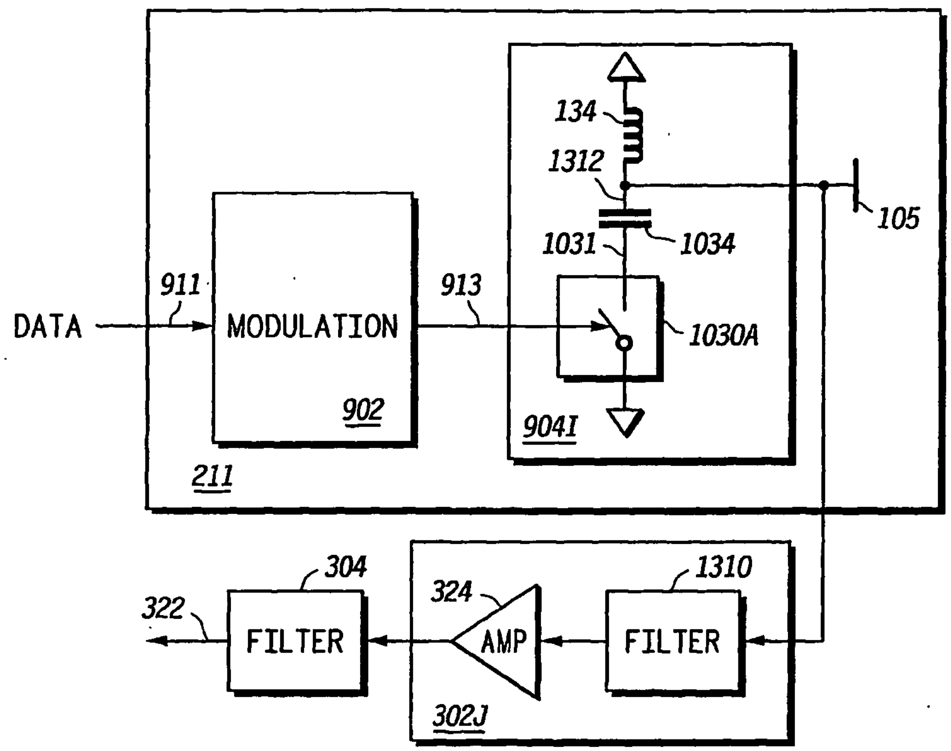


FIG.13A

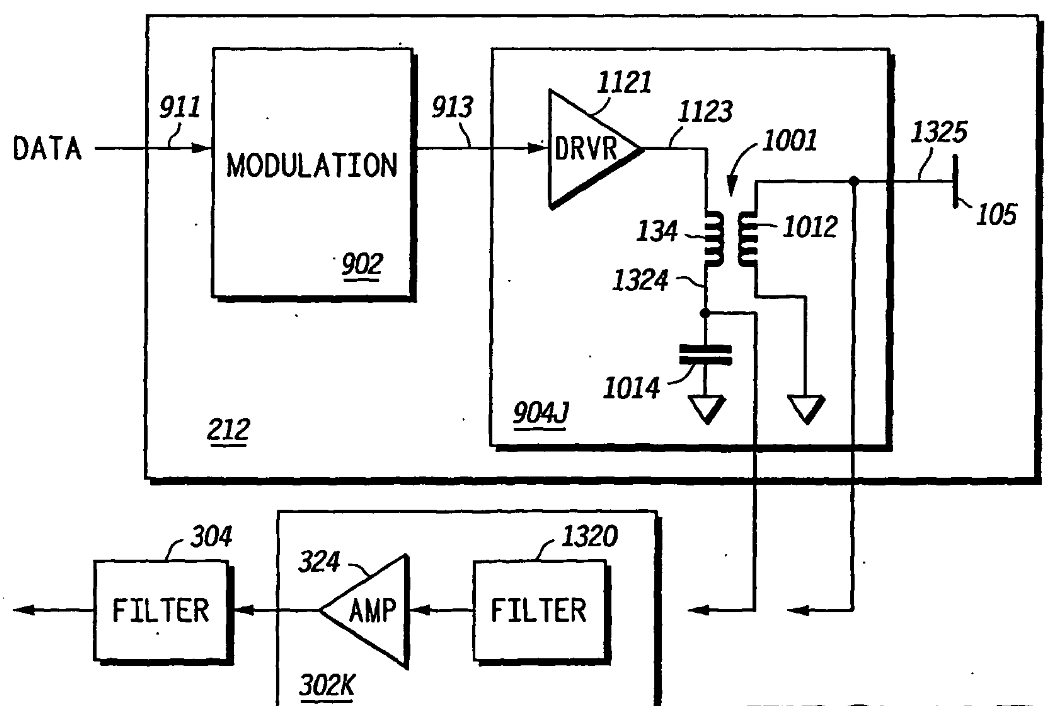


FIG.13B

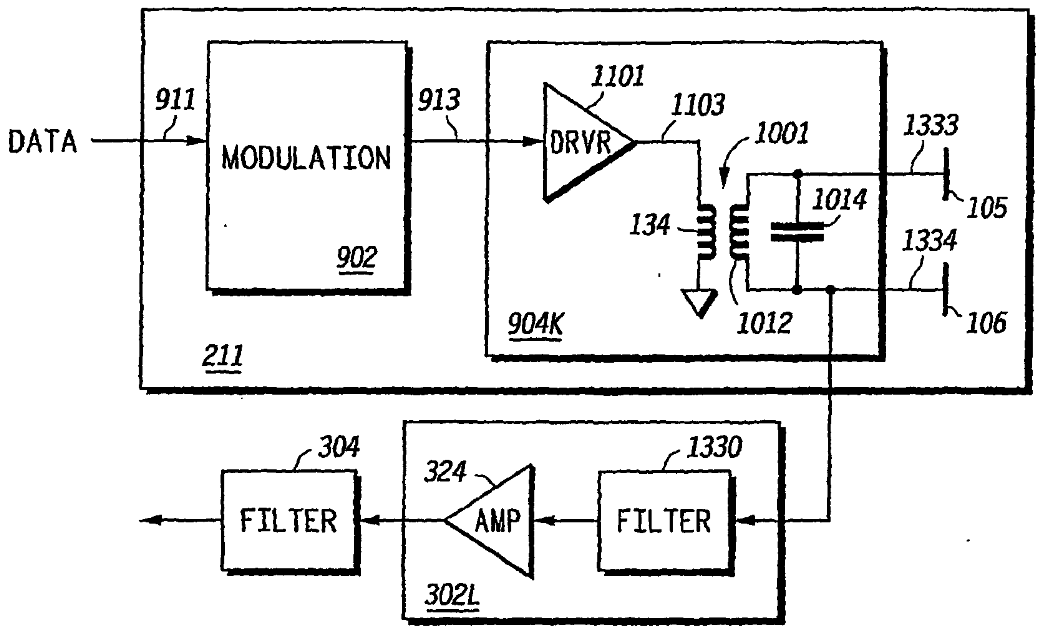

DATA
911
MODULATION
902
913
1101
DRVR
1103
1001
134
1014
1012
904K
1333
105
1334
106
211
304
FILTER
324
AMP
1330
FILTER
302L

FIG.13C

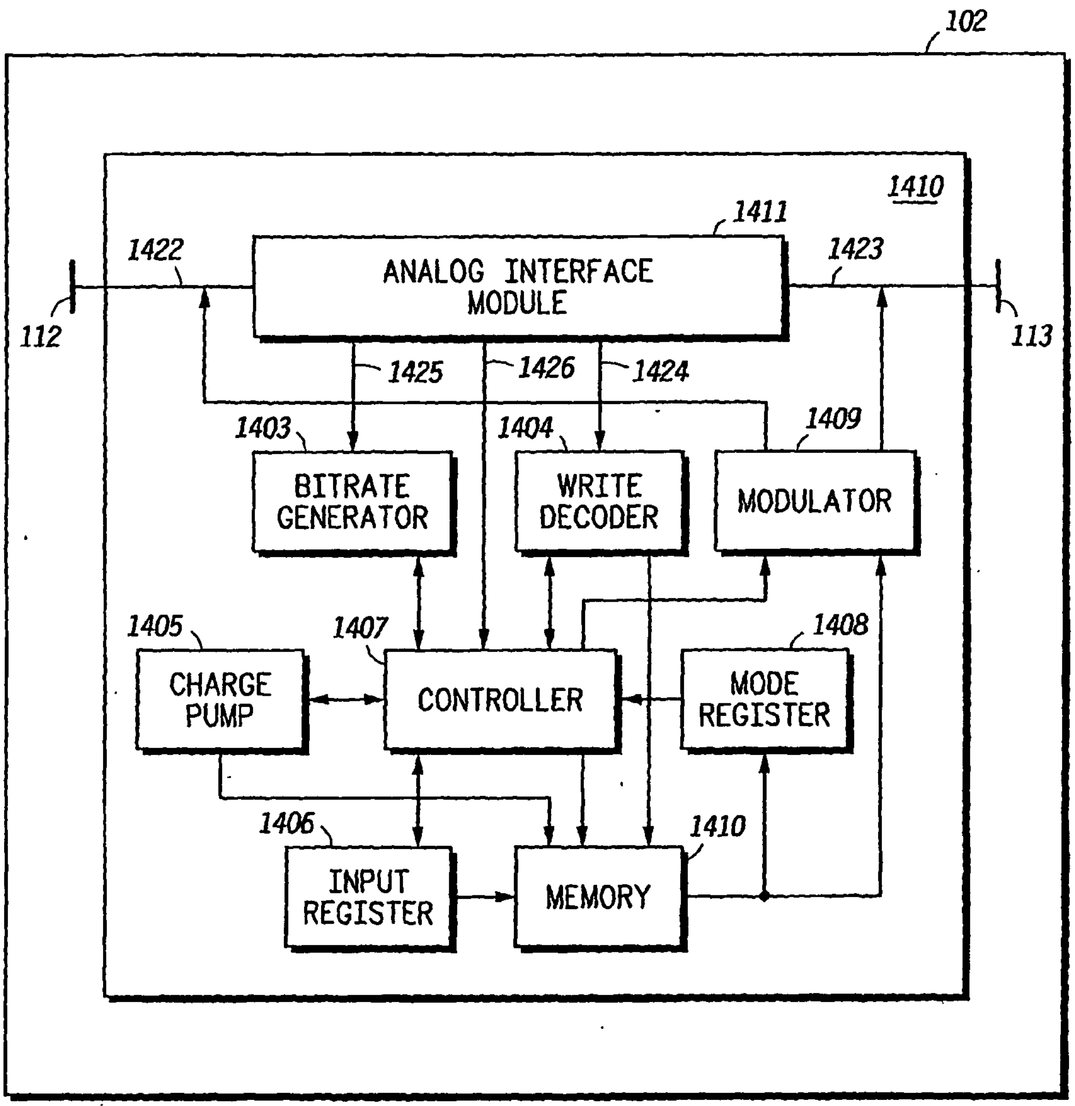

102
1410
1411
ANALOG INTERFACE MODULE
1422
1423
112
113
1425
1426
1424
1403
1404
1409
BITRATE GENERATOR
WRITE DECODER
MODULATOR
1405
1407
1408
CHARGE PUMP
CONTROLLER
MODE REGISTER
1406
1410
INPUT REGISTER
MEMORY

FIG.14

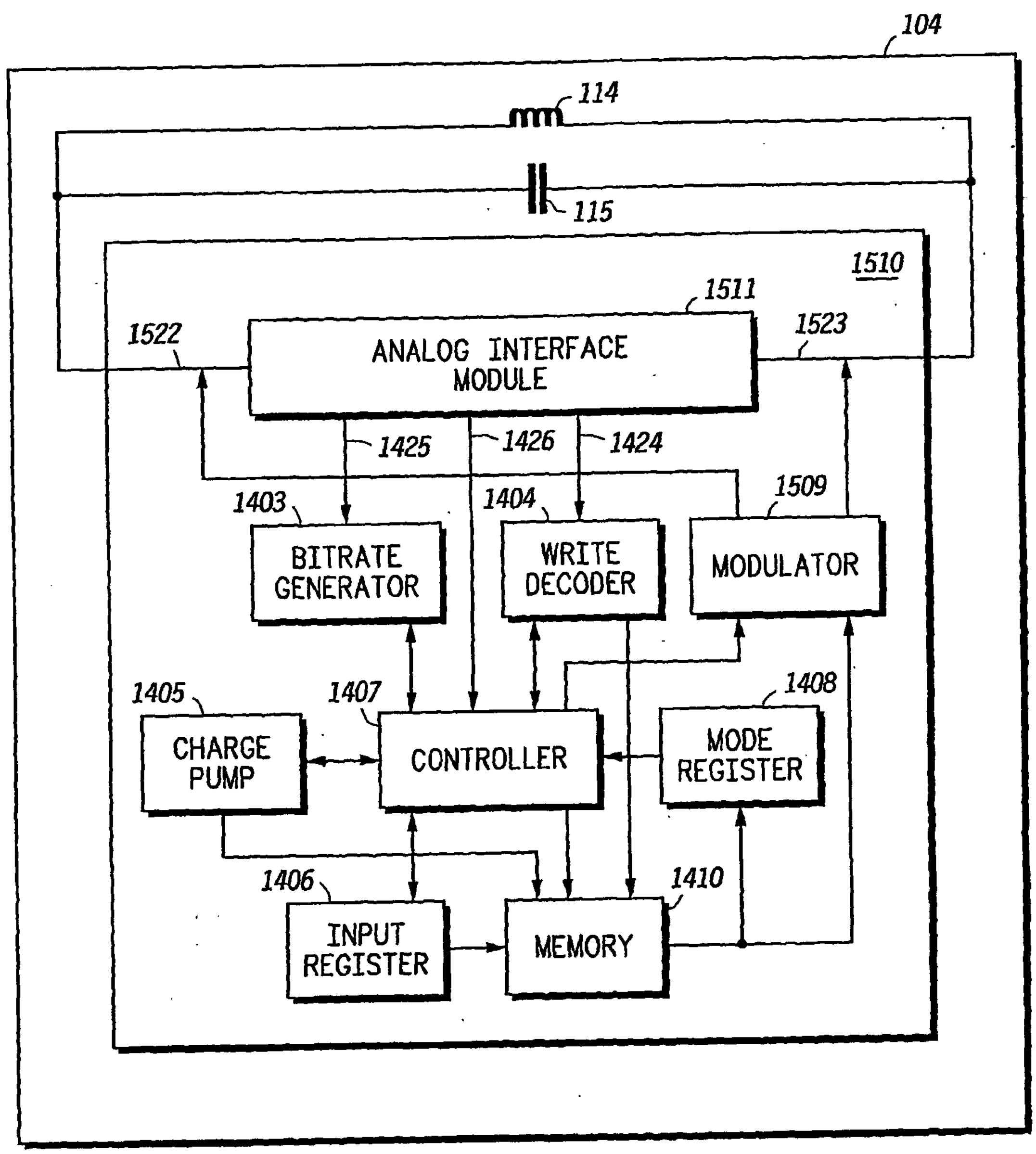

104
114
115
1510
1511
1522
ANALOG INTERFACE MODULE
1523
1425
1426
1424
1509
1403
1404
BITRATE GENERATOR
WRITE DECODER
MODULATOR
1405
1407
1408
CHARGE PUMP
CONTROLLER
MODE REGISTER
1406
1410
INPUT REGISTER
MEMORY

FIG.15

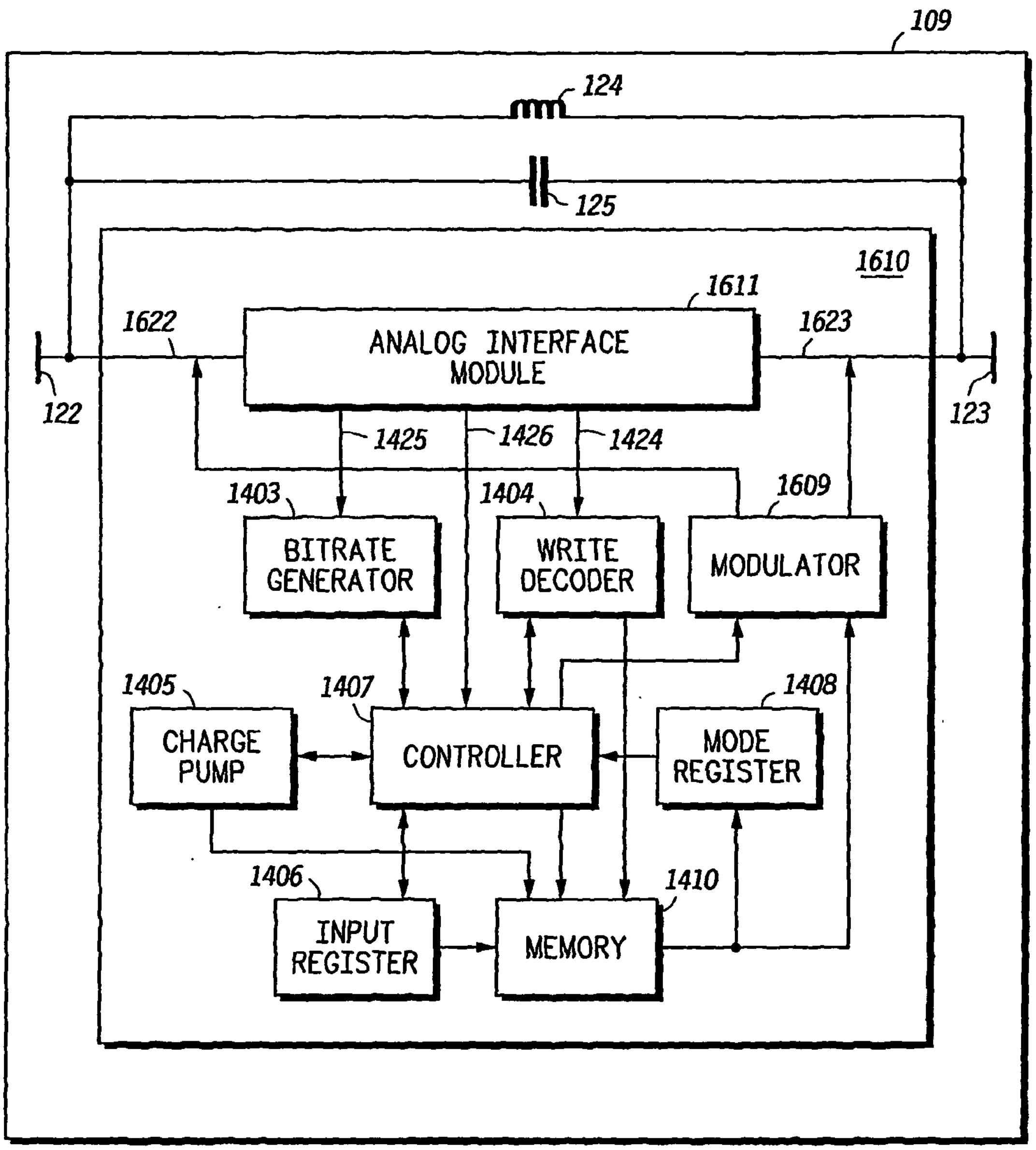

109
124
125
1610
1611
1622
1623
ANALOG INTERFACE MODULE
122
123
1425
1426
1424
1403
1404
1609
BITRATE GENERATOR
WRITE DECODER
MODULATOR
1405
1407
1408
CHARGE PUMP
CONTROLLER
MODE REGISTER
1406
1410
INPUT REGISTER
MEMORY

FIG.16

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US01/07389

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :G08B 13/14
US CL : 340/572.1
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 340/572.1 , 572.4 , 572.7 , 825.27 , 825.54 , 568 ; 235/440 , 449 , 380 ; 455/127 , 571

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EAST
electrostatic and electromagnetic and RFID or radio frequency identification

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	US 6,122,492 A (SEARS) 19 September 2000, fig.1, col.3, lines 11-32, fig.4, col.5, lines 1-41.	1-2, 4-5, 8-9
Y	US 5,781,111 A (EASTER ET AL.) 14 July 1998, figs.3-4, col.3, lines 34-54.	3, 6-7, 10
Y	US 4,742,470 A (JUENGEL) 03 May 1988, figs.1-2,11, col.3, lines 16-22 and col.5, lines 22-53.	3, 6-7, 10

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 APRIL 2001	23 MAY 2001

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	HOFSASS, JEFFERY Telephone No. (703) 305-4717